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Long-Term Effects of Land Application of Domestic Wastewater: Milton, Wisconsin Rapid Infiltration Site

Benham-Blair and Affiliates, Inc, Oklahoma City, OK

Prepared for

Robert S Kerr Environmental Research Lab, Ada, OK

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Robert S. Kerr Environmental Research
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Milton, Wisconsin
Rapid Infiltration
Site

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Milton, Wisconsin, Rapid Infiltration Site

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FOREWORD

The Environmental Protection Agency was established to coordinate the administration of major Federal programs designed to protect the quality of our environment.

An important part of the agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities. As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs including the development and demonstration of soil and other natural systems for the treatment and management of municipal wastewaters.

Although land application of municipal wastewaters has been practiced for years, there has been a growing and widespread interest in this practice in recent years. The use of land application received major impetus with the passage of the 1972 amendments to the Federal Water Pollution Control Act. The 1977 amendments to the Act gave further encouragement to the use of land application and provided certain incentives for the funding of these systems through the construction grants program. With the widespread implementation of land application systems, there is an urgent need for answers to several major questions. One of these questions regards the long-term effects of land application on the soil, crops, groundwater, and other environmental components. This report is one in a series of ten which documents the effects of long-term wastewater application at selected irrigation and rapid infiltration study sites. These case studies should provide new insight into the long-term effects of land application of municipal wastewaters.

This report contributes to the knowledge which is essential for the EPA to meet the requirements of environmental laws and enforce pollution control standards which are reasonable, cost effective, and provide adequate protection for the American public.

William C. Galegar

William C. Galegar
Director

Robert S. Kerr Environmental Research Laboratory

ABSTRACT

This report presents the findings of a research study on the long-term effects of applying treated domestic wastewater to an infiltration site at Milton, Wisconsin. On the test site a high-rate rapid infiltration method, applying effluent at an estimated rate of 244 meter (m) [800 feet (ft)] per year, had been used for about 20 years. Water and soil samples from this site were compared with similar samples from an upstream control area not receiving wastewater application.

Data on a number of parameters were evaluated against information about the natural features of the Milton physiographic region. Methods used in the field and laboratory analyses are described in sufficient detail to provide a basis for comparison of these results to other studies.

An essential aspect of evaluating water analyses is understanding the hydrogeology of the area. Knowledge of depth and movement of groundwater and location and thickness of aquifers was essential in interpreting data from wells strategically placed on both test and control sites.

Differences in 13 mean concentrations of 48 parameters analyzed statistically were found to be significantly greater for the effluent applied to the test site than for the groundwater at the control site. Ten of the 13 parameters were significantly greater in the test site groundwater in the immediate vicinity of the infiltration lagoons than in the control site groundwater. Approximately 62 percent of the nitrogen and 65 percent of the phosphorus applied in the effluent were passing perimeter wells located 50 to 280 m (164 to 918 ft) downgradient from the infiltration lagoon.

Soil samples taken beneath and downstream from the infiltration lagoon indicated that accumulation of phosphorus, nitrogen, and zinc appeared to be localized within 150 m (500 ft) of the infiltration lagoon. However, soluble orthophosphate phosphorus continued to escape beyond this perimeter. Metal constituents are being removed effectively within a 150-m (500-ft) radius of the infiltration lagoon.

This report was submitted in partial fulfillment of Contract No. 68-02-2363 by Benham-Blair & Affiliates, Inc., as the principal contractor; Engineering Enterprises, Inc., as subcontractor; with three cooperating companies: Sheaffer and Roland, Inc.; D. E. Matschke Company; and W. J. Bauer Consulting Engineers, Inc.; under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from January, 1976, to November, 1977; work was completed as of July, 1978.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

acre-ft	--	acre-foot
BOD	--	biochemical oxygen demand
BOD ₅	--	5-day biochemical oxygen demand
cm	--	centimeters
cm/hr	--	centimeters per hour
COD	--	chemical oxygen demand
DO	--	dissolved oxygen
exch	--	exchangeable
extr	--	extractable
fecal coli	--	fecal coliform
g	--	grams
gal	--	gallons
GL	--	ground level
gpd	--	gallons per day
gpd/ft	--	gallons per day per foot
gpm	--	gallons per minute
ha	--	hectares
hr	--	hours
in	--	inches
in/hr	--	inches per hour
kg	--	kilograms
kg/ha	--	kilograms per hectare
kg/ha/yr	--	kilograms per hectare per year
km	--	kilometers
L	--	liters
L/s	--	liters per second
L/d/m	--	liters per day per meter
lb	--	pounds
lb/acre	--	pounds per acre
lb/acre/hr	--	pounds per acre per hour
m ₃	--	meters
m	--	cubic meters
MCL	--	maximum contaminant level
mg/g	--	milligrams per gram
mg/L	--	milligrams per liter
Mgal/d	--	million gallons per day
Mgal/d/ft	--	million gallons per day per foot
mi	--	miles
mL	--	milliliters
mm	--	millimeters

mo	--	month
ng/g	--	nanograms per gram
ng/L	--	nanograms per liter
nm	--	nanometer
sq ft	--	square feet
SR	--	slow rate irrigation
SS	--	suspended solids
SWL	--	static water level
TDS	--	total dissolved solids
TOC	--	top of casing
total coli	--	total coliform
yr	--	year
µg/g	--	micrograms per gram
µg/L	--	micrograms per liter
µmhos/cm	--	micromhos per centimeter
#/100 mL	--	number of coliform per 100 milliliters of sample

SYMBOLS

Al	--	aluminum	Na	--	sodium
As	--	arsenic	NH ₃	--	ammonia
B	--	boron	NH ₄	--	ammonium
Ca	--	calcium	Ni	--	nickel
Cd	--	cadmium	NO ₂	--	nitrite
Cl	--	chlorine	NO ₃	--	nitrate
Co	--	cobalt	P	--	phosphorus
Cr	--	chromium	Pb	--	lead
Cu	--	copper	S	--	sulfur
Fe	--	iron	Se	--	selenium
Hg	--	mercury	SO ₄	--	sulfate
H ₂ SO ₄	--	sulfuric acid	Zn	--	zinc
K	--	potassium	>	--	greater than
Mg	--	magnesium	<	--	less than
Mn	--	manganese	µ	--	micron
N	--	nitrogen			

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Each of the participating companies had a primary leader or coordinator who took major responsibility for bringing the project to completion. Ernest L. Koerner, Benham-Blair & Affiliates, Inc., was responsible for the overall supervision, chemical analyses, and editing and production of the final report. D. Alan Haws, Engineering Enterprises, Inc., was a senior author and project manager for field construction and sample collection. Donald E. Matschke, D. E. Matschke Company, and Herbert M. Schornick, Engineering Enterprises, Inc., developed the results and discussion and the statistical comparisons. Messrs. William J. Bauer, Keith E. Bennett, William H. Bellis, John S. Fryberger, Harold E. Namminga, W. Russell Street, Dennis G. Lund, Paul K. Law, Lelan K. Martin, Ronald F. Sober, and John R. Sheaffer also made substantial contributions to the project.

In addition, the cooperation and assistance of personnel from the city of Milton, Wisconsin, were appreciated.

SECTION 1

INTRODUCTION

Land application of domestic wastewater is not a new concept, although it has only been in recent years that land treatment has received renewed attention. The multiple advantages of land treatment have been documented by many studies, but almost without exception there has been a lack of data on long-term effects.

Since 1939 the sewage treatment effluent from the City of Milton has been infiltrated into the ground using a high-rate infiltration method as illustrated in Figure 1. In high-rate infiltration land treatment, the applied wastewater percolates through the soil and eventually reaches the groundwater. Removal of wastewater constituents such as suspended solids, biochemical oxygen demand (BOD), and coliform is accomplished by the filtering and straining action of the soil. Nitrogen removals are generally poor unless specific operating procedures are established to maximize denitrification.

Well-drained soil, which is essential for infiltration-percolation, includes sand, sandy loams, loamy sands, and gravel. Very coarse sand and gravel are not ideal because wastewater passes too rapidly through the first few feet of soil, where the major biological action takes place. These soils are also characterized by low ion exchange capacities, which limits the chemical retention of pollutants.

In this research study conducted over a one-year period, test and control plots were selected for comparison of certain parameters. Samples were collected of the sewage effluent, groundwater, and soils. Field laboratory analyses of some samples at the site and later, complete chemical laboratory analyses provided the data presented in this report.

The objective of the study was to investigate the long-term effects of applying wastewater effluent to the land. Possible heavy metal accumulation in soils; potential contamination of groundwater supplies with bacteria, phosphates, nitrates, organics, and other parameters were key issues addressed. The study was designed to delineate the zone of groundwater influence, identify the flow path from the site, and compare on-site and downgradient groundwater quality to upgradient control groundwater quality.

The infiltration site at Milton is located at an abandoned gravel pit of highly permeable sand and gravel. A single infiltration lagoon is flooded continuously with the major infiltration taking place at the perimeter near the surface of the standing pool of effluent in the basin. This type of operation is not conducive to nitrogen removal.

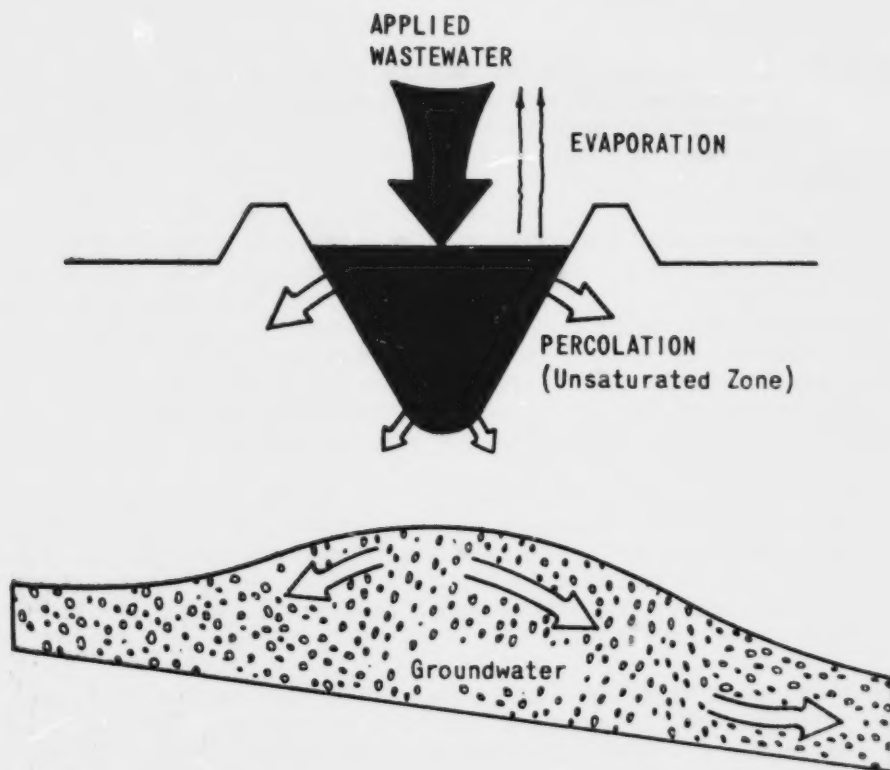


Figure 1. Rapid Infiltration

SECTION 2

CONCLUSIONS

An analysis of the waters and soils at the Milton site has produced findings related to the use of rapid infiltration for wastewater renovation. Major conclusions are as follows:

1. Fecal and total coliforms were consistently found in monitoring wells immediately beneath and adjacent to the infiltration lagoon. Although total coliforms were detected occasionally downgradient, fecal coliforms were found one time beyond 50 meters.
2. Metals such as zinc, which were measured in small concentrations in the treatment plant effluent, were removed and continue to be sufficiently immobilized by 50 m (164 ft) of travel in the alluvium after 20 years of lagoon infiltration.
3. Iron, manganese, and arsenic in the alluvium appeared to have been rendered more mobile as a result of the continuous flooding mode of operation and were found in low concentrations in the underlying groundwater at the test site. The source of these constituents in the groundwater appeared to be from the reduction of the oxidized hydroxides of these metals in the alluvium soils. The average iron concentration was 1.5 milligrams/meter (mg/L). At concentrations greater than 0.3 mg/L, iron can cause nuisance problems in plumbing from iron deposits and iron bacterial actions.
4. Toxic metals such as cadmium, lead, and mercury were demonstrably absent in the infiltration effluent and the underlying groundwater.
5. Lindane and 2,4-D were found in greater than background concentrations but within the proposed national limitations for primary drinking water concentrations in both the effluent and the infiltration groundwater.
6. Approximately 62 percent of the nitrogen and 65 percent of the phosphorus in the applied wastewater were passing perimeter wells located 50 to 280 m (164 to 918 ft) downgradient. Ammonium nitrogen is being introduced in to the groundwater at concentrations substantially exceeding drinking water criteria.
7. Chemical oxygen demand (COD) concentrations in groundwater measured at the test site perimeter wells were generally within the same range as the COD concentrations in the control groundwater.

8. The phosphorus removal capability of the shallow alluvium was comparatively low. Phosphorus concentrations remained at background levels in the deeper wells located in the less permeable alluvium.

SECTION 3

SITE-SELECTION PROCESS

GENERAL CRITERIA

Earlier Approaches

An earlier report (Bauer, 1976) defined a number of working approaches for the site-selection process. These were used initially to provide direction in the data-gathering phases. The earlier approaches included the following:

Soil Chemistry--

The chemical reaction of the soil with the chemicals in the applied wastewater takes place first in the upper layers of the soil. After these upper or plow layers have become saturated, reactions take place at progressively lower elevations. The distribution of accumulated chemicals resulting from the application of wastewater is studied from the point of view of this simple model of the process.

Hydrological--

Water moves through the earth in two major forms: (1) as soil water through the unsaturated zone, where the two fluid properties of fluid weight and surface tension dominate the movements, and (2) as groundwater through the saturated zone, where the two fluid properties of fluid weight and viscosity dominate the movements. Both of these movements are subject to the laws of fluid mechanics, permitting mathematical models to be set up for a particular site.

Such models are useful in guiding the exploratory and sampling program and in interpreting the results of such programs. The models enable one to define a "plume" of water that originates in the wastewater application site. This plume is then the only part of the soil and groundwater that is affected by the application of the wastewater. All other water outside this plume remains unaffected. This is an extremely important concept in guiding the program of sampling and in interpreting the results.

Application to Sites

The foregoing approaches aid in defining parameters that help to distinguish one site from another. Several of these parameters are as follows:

Uniform Permeability of Soils--

Each test site and control site should have the same type of soil with the same general, reasonably uniform permeability. The soil should not contain any well-defined channels through which the applied water could escape without contact with the chemicals in the soil mass.

Same Site--

The same site should have been used for a long time. If wastewater had been applied to first one and then another site over the period of operation, the concept of the long-term effect would not be applicable.

Depth to Groundwater--

The depth to the groundwater should be sufficient to permit some movement through the unsaturated zone, yet shallow enough to allow economical sampling of the water. The thickness of the aquifer should be adequate to permit a large body of soil to react with the applied wastewater.

Accounting for Chemical Elements--

Sufficient data should be available to estimate the total mass of chemical elements applied with the wastewater, the amount percolated through the soil, and the amount that has remained in the soil.

Constant Quality--

No substantial change should have occurred in the chemical quality of the applied wastewater over the period being studied.

Extraneous Sources--

If chemicals other than those in the wastewater have been applied on the study sites, such an application can introduce uncertainties into the operation that would make the analyses difficult. Other factors being equal, sites at which other sources of chemicals have been applied should be avoided.

General Criteria Supplied by EPA

The EPA also specified certain other general criteria for the selection of sites. These criteria are as follows:

1. Flow rates should be at least 4.38 liters/second (L/s) [million gallons/day (Mgal/d)].
2. Historical records should be available for at least 10 years.
3. The applied wastewater should be effluent from **either primary or secondary treatment.**
4. A good control site should be available within a reasonable distance and have the same general type of soil and hydrogeological conditions.

NORTH CENTRAL STATES SITE

Preliminary Evaluations

The geographical area involved comprised the states of Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio. STORET data supplied by the EPA was examined for information about potential sites in each of these states. A survey was then conducted to obtain further information about these sites and any others that might be candidates for study. The survey disclosed that examples of land application of wastewater were to be found only in the states of Wisconsin and Michigan within the area designated as North Central States. After eliminating potential sites that were found to be either too small or too recent, only three potential sites remained, and these were visited for further evaluation.

Site Visits

Table 1 summarizes the comparison of the potential sites visited at Milton, Fontana, and Williams Bay, Wisconsin. Each had practiced high-rate infiltration of sewage effluent for about 40 years or longer. Two of the sites are located on the shores of Lake Geneva and have similar soils and geology. The third, Milton, is located within an hour's drive from the other two, but is on different soils, which had a major bearing in the final selection. As is indicated in Table 1, the sites at Fontana and Williams Bay were less desirable because of the high degree of variability in the underlying formations. It was believed that this would have resulted in pronounced channelization of the percolated water, making it difficult if not impossible to obtain a representative sampling of the soils that would have interacted with the percolating water. In contrast, the Milton site was underlain by relatively uniform soils that would permit more representative sampling to be achieved. The flow, which had been relatively consistent in quality and quantity, had been applied to the same area for about 40 years.

TABLE 1. COMPARISON OF SITES LOCATED IN NORTH CENTRAL STATES^a

Location	Uniform Permeability	Same Site	Groundwater Depth	Aquifer Thickness	Mass Balance	Wastewater Quality	Extraneous Sources	Total
Milton, WI ^b	+1*	+1	+1	+1	-1	+1	-1	3
Fontana, WI ^c	-1	0	+1	+1	-1	0	+1	1
Williams Bay, WI	-1	0	+1	+1	-1	0	+1	1

*+1 = parameter favorable; -1 = parameter unfavorable; 0 = neutral

Notes:

a. Other sites investigated were eliminated for the following reasons:

1. No application of municipal effluent: Minnesota, Iowa, Illinois, Indiana, Ohio.
2. Too recent: King, WI; Wautoma, WI; Cassopolis, MI; East Jordan, MI; Harbor Springs, MI; Harrison, MI; Middleville, MI; Ottawa County Road Comm., MI; Fremont, MI (infiltration system only).
3. Too small: Spring Green, WI; Gastra, MI.

b. The problem at Milton is the presence of natural basins in which storm runoff percolates into the same aquifer into which the sewage effluent is discharged. The most significant of these basins is one immediately adjacent to the sewage percolation basin which receives the drainage from about 260 acres of land. It is estimated that the input into this basin would be about 150 acre-feet per year. By comparison, the input into the sewage effluent basin is estimated to be 0.33 Mgal/d or 370 acre-feet per year.

c. Fontana and Williams Bay are both located on glacial drift with considerable segregation of materials as to permeability; thus, the movement of the percolated water is dominated by channelization through the veins of more permeable materials. By contrast, the formation at Milton is more uniform in permeability.

SECTION 4

DESCRIPTION OF SITE

GENERAL

Milton is located in Rock County in south central Wisconsin, approximately 40 miles southeast of Madison, Wisconsin. Milton has a population of about 4,000, which remains relatively constant throughout the year. It is the home of Milton College, a four-year college with an enrollment of 500 students, and of several small industries, none of which contribute any unusual loadings to the treatment plant. The sewage treatment plant is located in the center of Section 27, T. 4 N., R. 13 E.

TOPOGRAPHY

The sewage treatment plant is located at an old gravel pit on glacial moraine sediments of high relief. Within the Milton area, surface drainage is poorly developed; much of the surface runoff collects in low areas, creating some natural lakes or swamps. A portion of this water becomes additional groundwater recharge that eventually discharges to the Rock River. Close to the river and streams where surface drainage is developed, the average annual runoff is about 18 centimeters (cm) [7 inches (in)] per year.

TEST SITE

The Milton wastewater treatment plant consists of secondary treatment followed by discharge to three lagoons. The first two lagoons provide detention time only, whereas the third lagoon is maintained as an infiltration pond. The lagoons are continually flooded except as required to maintain infiltration, and the third lagoon is drained and cleaned with a drag line approximately every two years.

This third lagoon covers an area of approximately $1,860 \text{ m}^2$ ($20,000 \text{ ft}^2$) with an average annual inflow of 14 L/s [330,000 gallons/day (gpd)], which results in a loading rate of 244 m (800 ft) per year or 0.67 m (2.2 ft) per day.

The sewage treatment plant is located within a 10 to 30 foot excavation of an abandoned gravel pit at an elevation of approximately 855 feet above mean sea level (Figure 2). The surrounding unexcavated area to the north and east has an elevation of approximately 875 feet, whereas the water surface elevation of the infiltration pond (third lagoon) is normally about 851 feet. Over the years this pond has been excavated to an elevation of 833 feet. The water table below the bottom of the pond occurs at an elevation of 825 feet.

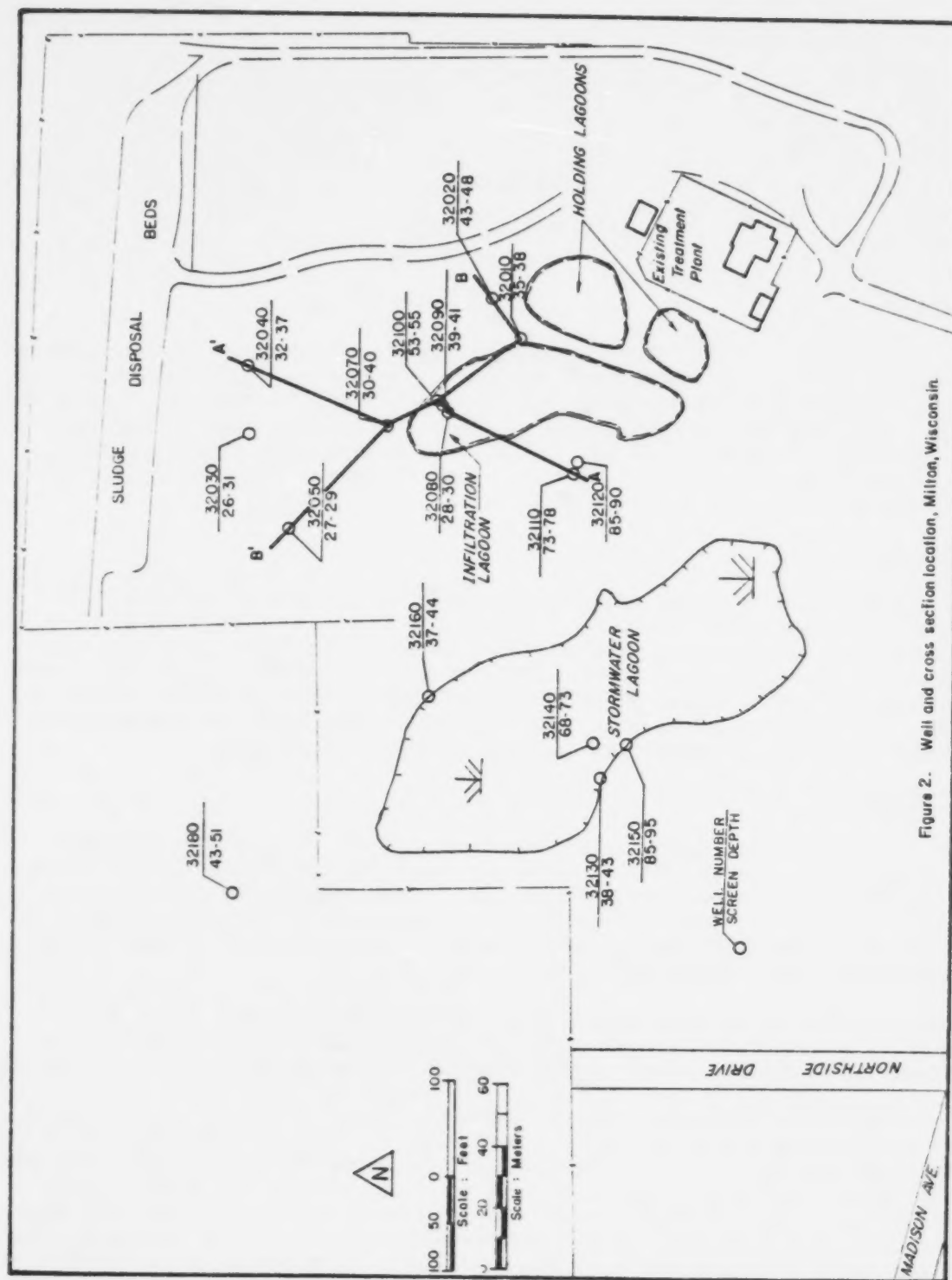


Figure 2. Well and cross section location, Milton, Wisconsin

This is illustrated in cross sections A-A' and B-B' (Figures 3 and 4).

A natural stormwater basin (pond) located immediately west of the infiltration pond collects surface runoff averaging approximately 18.5 hectare-meters (ha-m) (150 acre-ft) per year from a drainage area of about 105 ha (260 acres). This stormwater basin was a complicating factor that required consideration and monitoring to evaluate the effects of the adjacent infiltration pond. The stormwater basin normally contained only a few feet of water within a small silty and impermeable area. During runoff events the water ran out over adjacent permeable pasture land, resulting in rapid infiltration of the excess water.

Sludge is disposed in beds at the top of the hill at an elevation of approximately 875 feet. Recharge to and groundwater flows from the sludge beds move initially east and then north around the monitoring wells (Figures 5 and 6).

CONTROL WELLS

One control well, 31060, was located upgradient from the infiltration pond. Samples of the groundwater and soils unaffected by the infiltrated effluent were obtained at this location. An upstream existing domestic well was initially selected as a control well. It was assigned the number 31210 and sampled three times.

GEOLOGY AND GROUNDWATER HYDROLOGY

The rapid infiltration wastewater lagoon site used by Milton is located on glacial moraine sediments. This morainal area has high relief, sometimes as much as 30 m (about 98 ft) over a horizontal distance of about 1.6 kilometers (km) [1 mile (mi)]. These glacial sediments generally consist of unsorted mixtures of clay, silt, sand, and gravel, with stratified accumulations of sand and gravel.

Beneath the Pleistocene glacial deposits are gray to yellow-gray dolomite, sandstone, and green shale of the Platteville-Galena unit (Ordovician Age). This bedrock unit underlies the glacial material throughout Rock County except where preglacial erosion cuts down to the underlying St. Peter Sandstone (Ordovician Age), Prairie du Chien Group (Ordovician Age), or Trempealeau Formation (Cambrian Age). The ancestral Rock River valley occurs just west of Milton, and there is an erosional channel beneath Milton that joins the ancestral Rock River channel. Erosion that formed these channels cut into the Trempealeau Formation, and in places more than 90 m (300 ft) of glacial deposits presently fill these old channels and cover the bedrock units (LeRoux, 1963).

A City of Milton well (SE, SE, Sec. 27, T. 4 N., R. 13 E.), designated No. 6 for this study (Figure 5), had about 84 m (274 ft) of glacial silts, sands, and gravels resting on the Trempealeau dolomite. There were 20 wells drilled for this project (Figures 2 and 5), with the maximum penetration of the glacial material being about 27 m (90 ft) in well 32170. The deepest well was 32150, which was drilled to 29.6 m (97 ft); however, the last 3 m

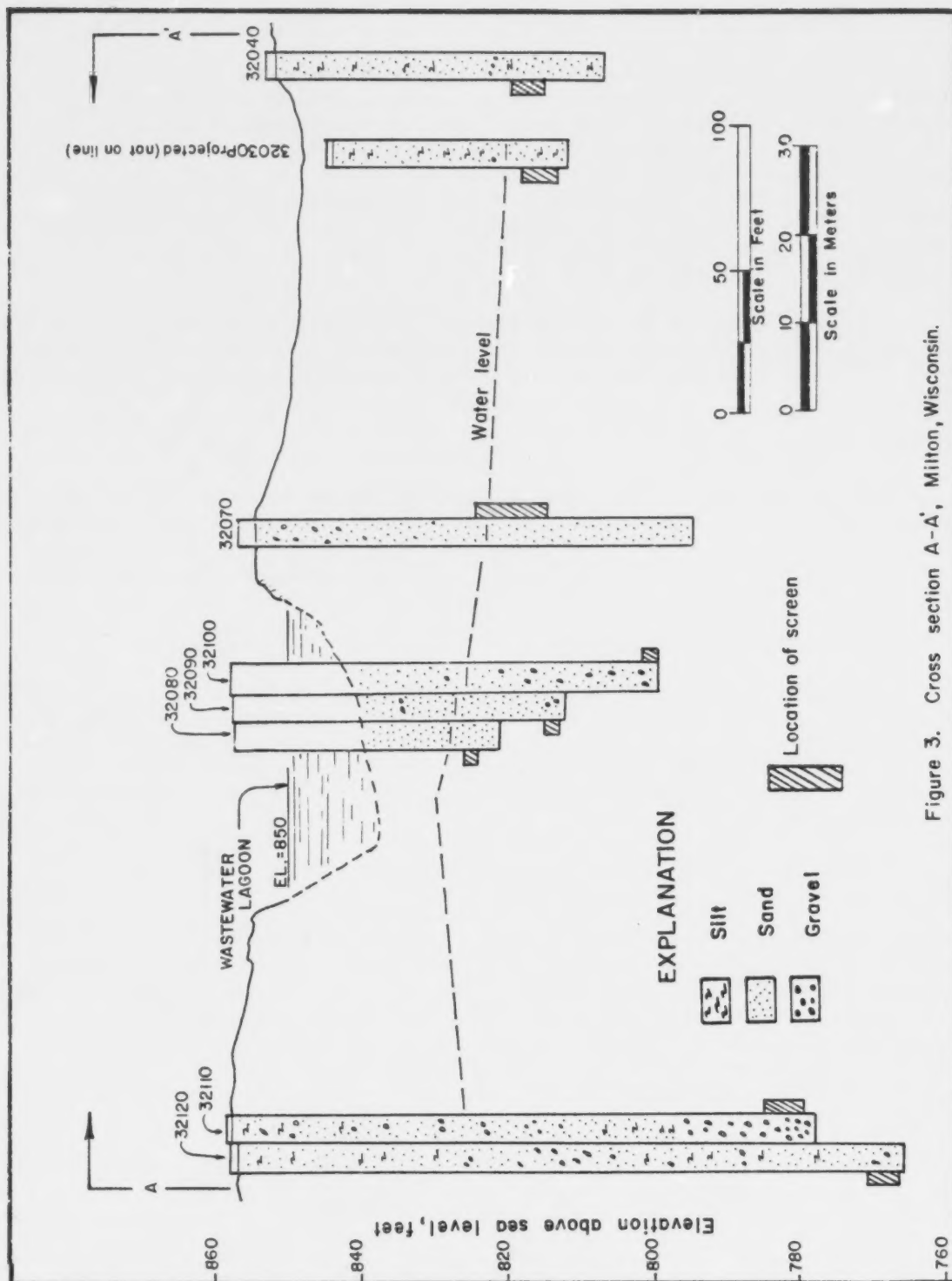


Figure 3. Cross section A-A', Milton, Wisconsin.

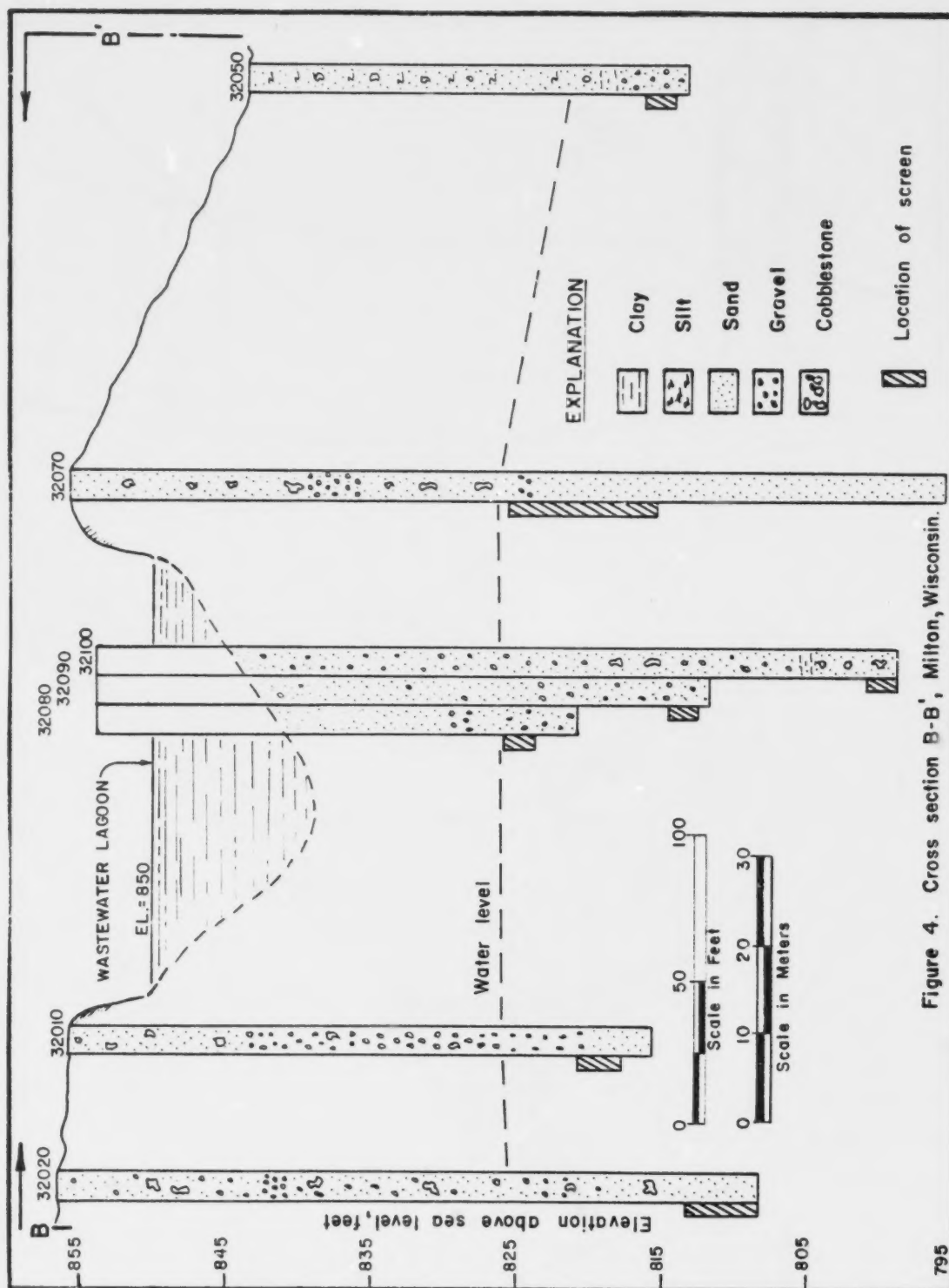


Figure 4. Cross section B-B', Milton, Wisconsin.

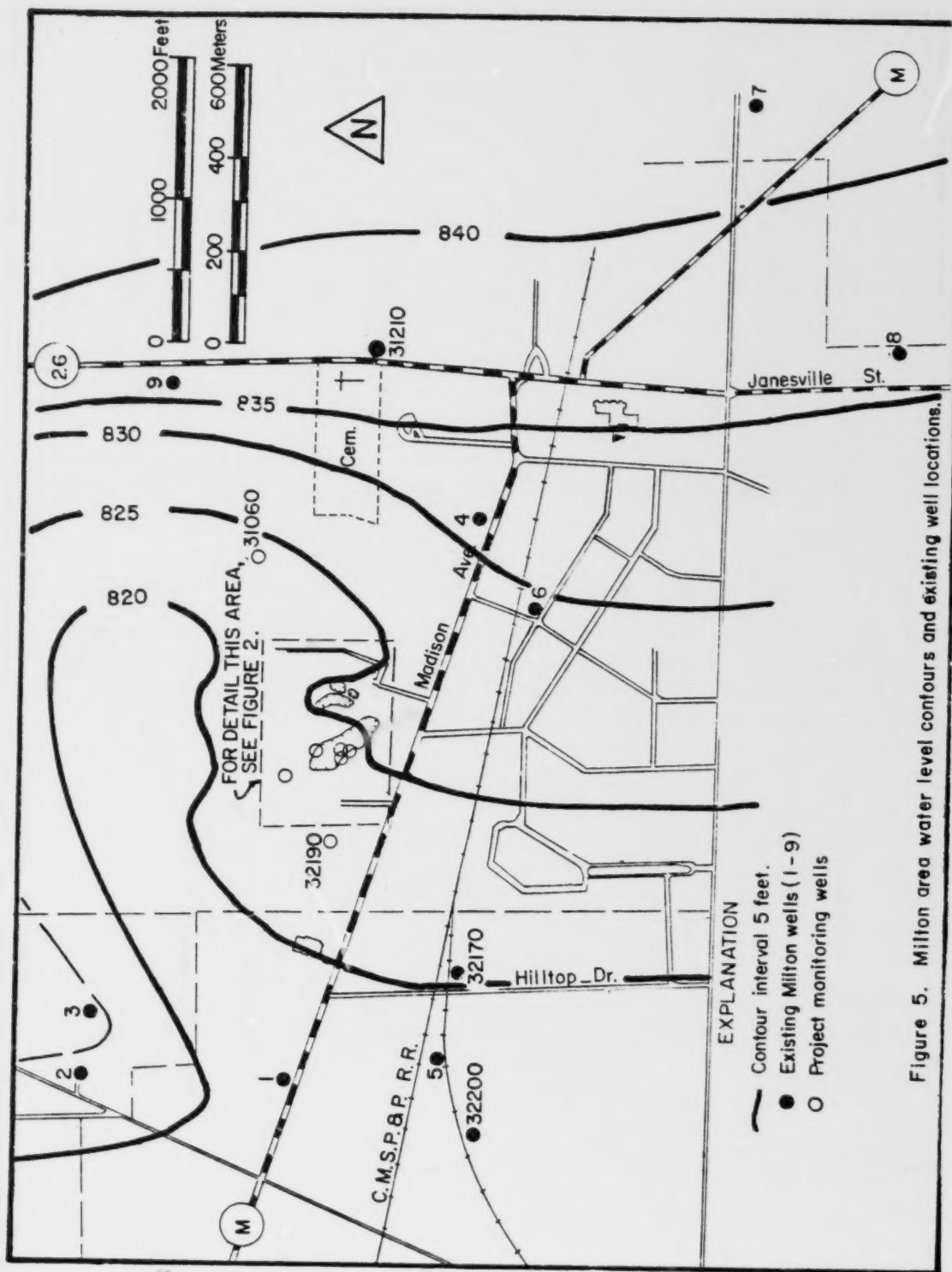


Figure 5. Milton area water level contours and existing well locations.

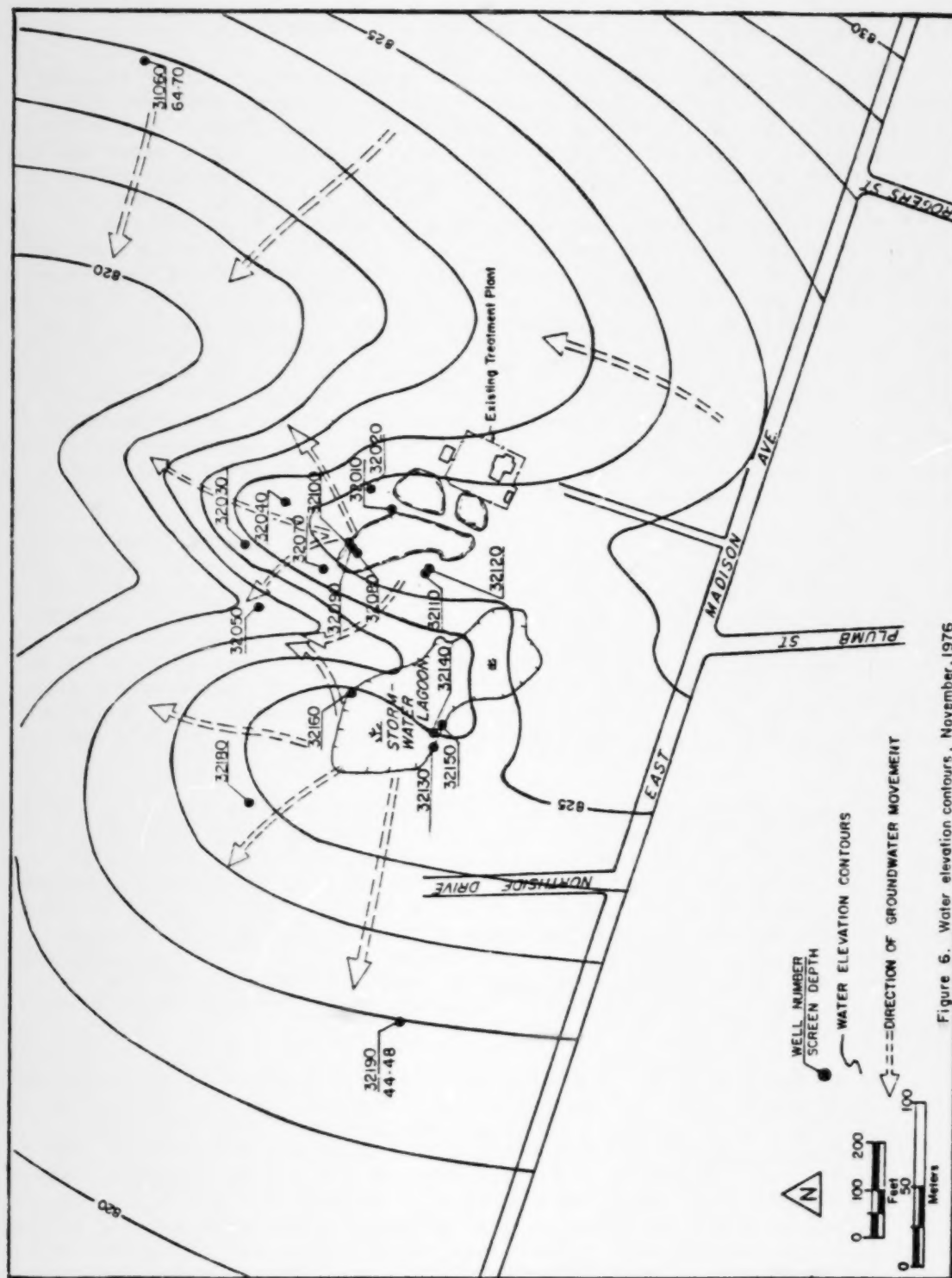


Figure 6. Water elevation contours, November, 1976

(12 ft) were probably in the Platteville dolomite (Appendix A).

The rate of groundwater movement in the vicinity of the lagoon site was estimated from the median specific capacity value for large diameter, high-capacity wells in the glacial outwash sediments (LeRoux, 1963). This value (Q/s) is 24.9 L/s per meter (120 gpm per ft) of drawdown. For a water table aquifer, such a value should result from a coefficient of transmissibility of 2.24×10^6 liters per day per meter width (180,000 gpd per ft). From LeRoux's data, the saturated thickness was approximately 46 m (150 ft), which will give a calculated permeability of 5.66×10^{-2} cm² per sec. per cm² (1,200 gpd per ft²). The groundwater gradient in the vicinity of the wastewater lagoons was 0.012 (Figure 6), and if an effective porosity of 20 percent is assumed, the flow rate beneath the lagoons was about 3 m (10 ft) per day. Using the same calculations with LeRoux's data for the minimum specific capacity, 2.6 liters per second per meter (12 gpm per ft), the flow rate was a factor of 10 less, or about 0.3 m per day (1 ft per day). This range of 0.3 to 3 m per day (1 to 10 ft per day) for the velocity of the groundwater movement away from the lagoons was only an estimate, and there were certainly some gravel layers in which the flow was faster and some silty sand zones in which the velocity was much slower.

Groundwater recharge to the glacial sediments came directly from precipitation. The average annual precipitation in Rock County is about 81 cm (32 in) (LeRoux, 1963), although the Janesville station reported only 60 cm (23.8 in) for 1976. Groundwater recharge in this part of Wisconsin has been reported to be about 12 percent of the average annual precipitation. However, in poorly drained areas this percentage would be higher, perhaps 15 percent, with a corresponding decrease in surface runoff. Water levels are generally highest in the spring, because recharge is greatest, but decrease through the summer, finally reaching the lowest level during the fall and winter.

The bedrock units dip to the east-southeast at a gentle rate of 1.5 to 2.0 m per km (8 to 10 ft per mi). Where the bedrock is at or near the surface or covered with only a thin veneer of glacial drift, the groundwater is probably in an unconfined state. In the Milton area the bedrock units are generally covered by about 30 m (100 ft) of glacial material. This, in conjunction with the occurrence of impermeable zones in the bedrock, provides artesian conditions for the bedrock groundwater. LeRoux (1963), nevertheless, considers that the leaky nature of the impermeable zones does not totally confine the groundwater and that all the water zones will have essentially the same water level.

The groundwater in the glacial material should be essentially unconfined. It was also possible to have local artesian conditions, due to impermeable clay lenses and local perched unconfined conditions resulting from them. Water level measurements for this study (Table 2) showed variations of the static water level from deep to shallow zones in the glacial aquifer. Comparing wells 32130 and 32140, this difference was probably due to the clay layer, which retarded the downward water movement (Appendix A) and had a lower water level than either well 32140 or well 32130 (Table 2). These data reflect the complexity of groundwater equilibrium and are a reminder that the

[illegible]17

infiltrated wastewater does not move downward and laterally from the pits in a simple flow pattern.

LeRoux's (1963) map of the piezometric surface (1958 data) shows that the regional surface in the Milton area slopes to the northwest at a rate of about 2.5 m/km (13 ft/mi) towards the present-day Rock River channel. The water table surface in this study (Figure 5) indicated a slope of about 3.6 m/km (19 ft/mi) towards the west. These general contours, developed from existing water wells in the vicinity (Appendix C), indicated a groundwater low or deflection just north of the wastewater lagoons and stormwater basin. The general five-foot contours also suggested that the general flow direction from the wastewater lagoons was initially north, east, and west, then to the north towards the water-table low, and then to the southwest towards the Rock River channel.

The detailed water-level contours for November, 1976, (Figure 6) indicated mounding of the groundwater beneath the wastewater lagoons and the stormwater runoff basin. The slope of this surface was about 12 m/km (63 ft/mi) towards the north. There was also movement from the mound beneath the wastewater lagoon towards the west to a low area that separates the lagoon wastewater mound from the storm runoff mound. In this low area the two waters mix and continue movement to the northeast. The groundwater beneath the storm runoff basin also moves away from the mound towards the east-northeast, following the regional trend. However, the groundwater mound beneath the stormwater basin does not exist the year round. As this mound disappeared (Figure 7), as indicated by detailed water-level contours during April, 1977, flow from the wastewater mound could move beneath the storm basin and mix with the residual stormwater.

The change in groundwater flow patterns could have been caused by high surface-water runoff events that resulted in increased infiltration at the stormwater ponds and/or high summer effluent flows resulting in more infiltration from the wastewater ponds. If this is true, then the flow pattern shown by the November, 1976, contours and monitored at well 32050 would consist primarily of infiltrated wastewater that had previously flowed under the stormwater basin. These local seasonal variations of the groundwater movement in the vicinity of the wastewater infiltration ponds made tracing the chemical plume from the wastewater difficult.

The groundwater contours (Figures 6 and 7) show that well 31060 represented the off-site upstream groundwater regime, and the water quality should be representative of the glacial deposits unaffected by wastewater.

Aquifer pumping tests were not conducted at the Milton site, principally because of construction cost constraints. An example of the water-yielding characteristics of the Pleistocene glacial sediments was provided by two wells in the Janesville area (five miles south of Milton). One well yielded nearly 79 L/s for 24 hours with 0.3 m of drawdown (1,250 gpm/ft), and another yielded about 344 L/s for 24 hours with 2.1 m of drawdown (5,450 gpm/ft) (LeRoux, 1963). These data suggest that the coefficient of transmissibility for the permeable zones in the glacial sediments would be around 12.4 million liters per day per meter (1 Mgal/ft). This rather high transmissibility

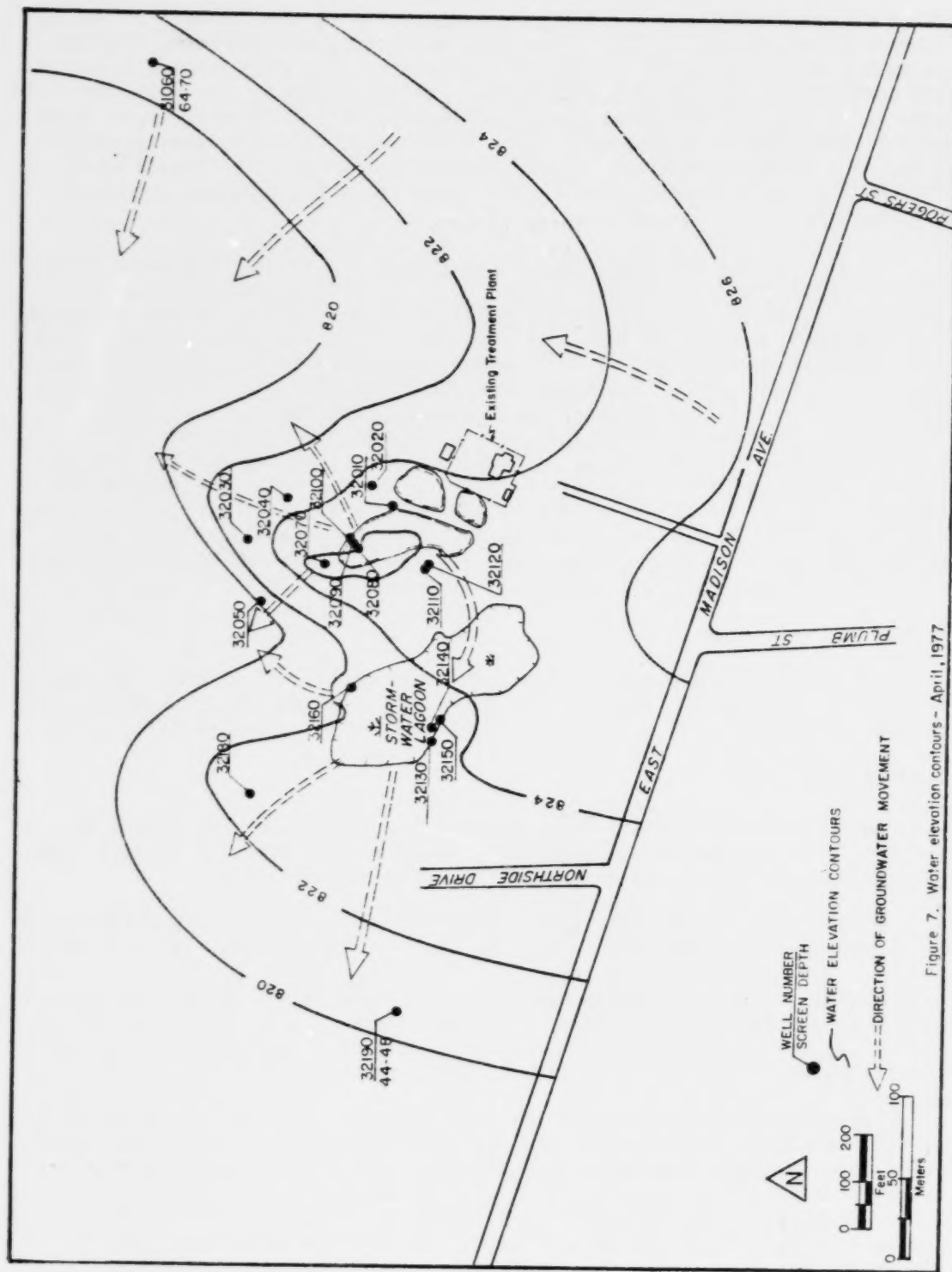


Figure 7. Water elevation contours - April, 1977

value was also confirmed for the glacial deposits in the vicinity of Milton (Strand & Associates, 1975). These data must certainly represent the most permeable gravel zones of the glacial sediments. The wide spacing shown by the contours of the regional piezometric surface indicates the most permeable area is in the old Rock River channel (LeRouz, 1963). These contours become more closely spaced in the vicinity of Milton, indicating a lower permeability. The principal avenues of dispersion for the infiltrated wastewater are the shallow, thin, clean gravel layers found below the groundwater table (Appendix A).

It is probably not justifiable to rigorously correlate the water level recorder data from the project (Figure 8). The record began in October, 1976, and ended in June, 1977. The water level was on the decline during the fall and early winter, as should be expected. The rise in water level from late February to early March, 1977, was probably due to runoff from snowmelt, since there were several inches of snow on the ground in early February and the daily high temperature began to increase during the last two-thirds of the month. This corresponded with the filling of the storm runoff basin, which occurred prior to the April sampling round. The decline for the remainder of March, April, and May was probably due to natural discharge and transpiration of the newly leafing vegetation. A subsequent rise from June through October would probably correspond to increased wastewater flows during the summer months, because the high water levels during October, 1976, occurred during a time when the basin was almost dry.

SOILS

The rapid infiltration site at Milton was not a soil system. The infiltration was through the floor of old gravel pits consisting of geologic formations of glacial till. See the geology section for detailed information.

CLIMATE

Rock County, Wisconsin, has a continental climate, characterized by marked changes in weather. The area is influenced by pressure systems that move southward from Canada and eastward across the continent.

Winters are relatively cloudy, cold, and snowy. Rivers and lakes begin to freeze over in November, and the ice usually remains until early in April.

Spring is slow in coming, and periods of hard weather alternate with cold spells. Snowfall decreases as spring begins, and by the end of March nearly all the precipitation falls as rain. Table 3 gives temperature and precipitation data based on records at the Lake Geneva Weather Station.

The growing season averages 161 days per year. Annual precipitation is normally adequate for the crops grown, the driest part of the growing season being late in August and early in September. The average annual precipitation is about 84 cm (33 in), with about 60 percent occurring from April through August. From the middle of November to the end of March, most of the precipitation falls in the form of snow. The average annual snowfall is 109 cm (43 in).

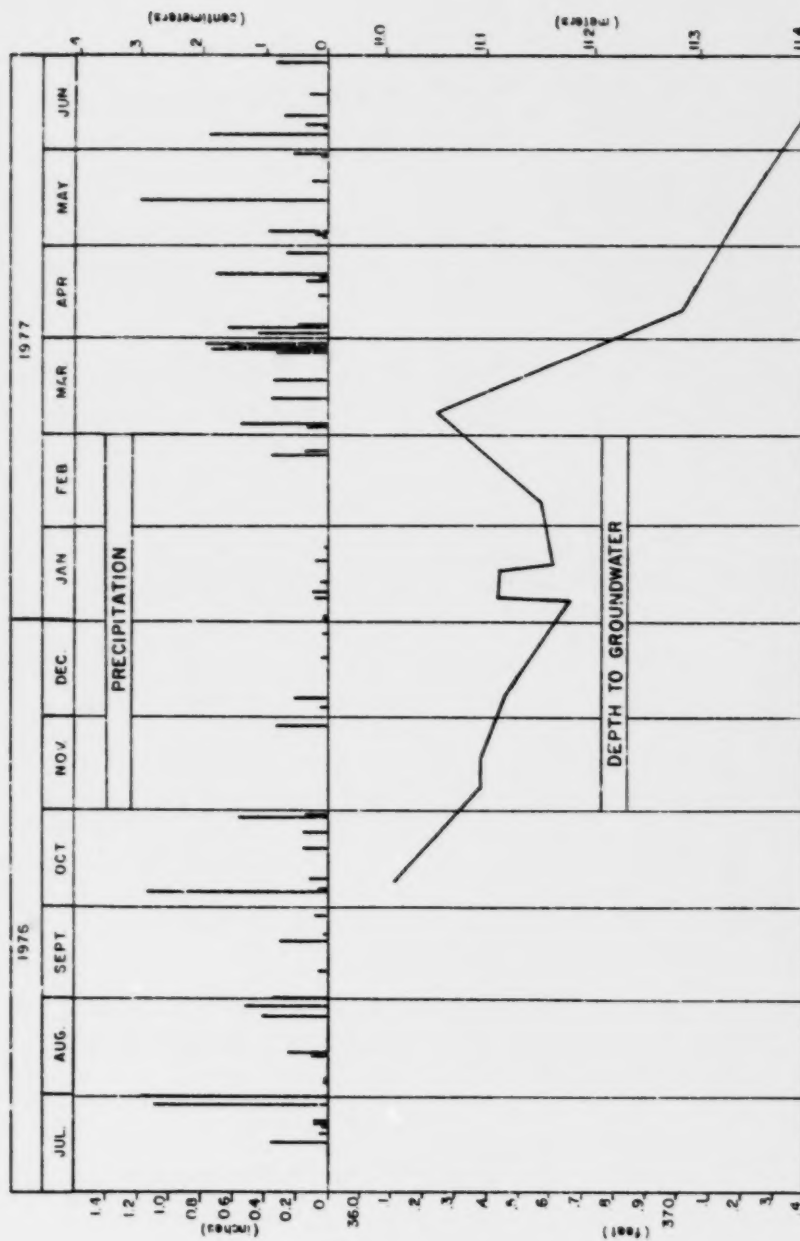


Figure 8. Test site hydrologic cycle.

TABLE 3. TEMPERATURE AND PRECIPITATION DATA^a

Month	Temperature				Precipitation			
	Average daily maximum (°F)	Average daily minimum (°F)	Two years in 10 will have at least 4 days with--		Average total (Inches)	Less than-- (Inches)	More than-- (Inches)	Average total (Inches)
			Maximum temperature equal to or higher than-- (°F)	Minimum temperature equal to or lower than-- (°F)				
January	29.8	13.2	46	-9	1.73	0.45	3.24	11.0
February	33.2	16.4	44	-6	1.26	0.51	2.36	5.5
March	42.6	24.5	60	11	2.55	0.86	3.98	10.1
April	58.6	36.4	77	25	3.24	0.94	4.78	1.1
May	69.6	45.9	85	33	3.69	1.37	6.15	0.1
June	79.2	56.8	93	45	4.46	1.41	5.63	0.0
July	84.0	61.9	93	52	4.18	1.01	7.66	0.0
August	82.6	61.3	93	51	3.60	1.40	7.38	0.0
September	74.1	52.4	90	40	1.98	1.28	6.57	0.0
October	63.7	42.7	79	29	2.13	0.74	4.55	0.0
November	45.0	28.7	64	12	2.16	0.43	4.34	4.5
December	33.2	18.6	47	-3	2.12	0.42	2.87	10.6
Year	58.0	38.2			33.10			43.1

^a All data based on records at Lake Geneva Weather Station.

The prevailing winds are from the west in winter and from the south in summer. The average annual lake evaporation is 76 cm (30 in), with 80 percent occurring from May through October.

Climatological data for the project period are shown in Table 4. The rainfall during 1976 was only 70 percent of normal with a corresponding increase in evaporation. During the first half of 1977, rainfall was about 90 percent of normal.

TABLE 4. RECENT CLIMATOLOGICAL DATA

Month	Average Temp. ^a (°F)	Precipitation ^a (inches)	Evaporation ^b (inches)
January, 1976	18.3	0.72	-----
February, 1976	31.1	1.29	-----
March, 1976	39.5	4.73	-----
April, 1976	51.7	2.63	-----
May, 1976	57.8	4.03	6.82
June, 1976	71.5	2.12	9.88
July, 1976	75.8	2.91	10.24
August, 1976	70.8	1.49	7.98
September, 1976	61.6	0.82	5.65
October, 1976	46.7	2.32	-----
November, 1976	29.0	0.37	-----
December, 1976	<u>15.8</u>	<u>0.38</u>	<u>-----</u>
Total 1976	47.5	23.81	40.57
January, 1977	5.2	0.53	-----
February, 1977	23.4	0.56	-----
March, 1977	41.3	4.06	-----
April, 1977	54.5	2.62	-----
May, 1977	67.0	2.19	8.99
June, 1977	<u>67.6</u>	<u>3.05</u>	<u>6.52</u>
Total, Jan- June 1977	43.2	13.01	15.51

^a Measured at Janesville, Wisconsin.

^b Measured at Arlington University Farm, Wisconsin.

LAND USE

Farmland in Rock County can be farmed intensively if adequate conservation practices are followed. Before the Civil War, wheat was the principal crop. After the Civil War, farmers diversified their crops by producing other grains in addition to wheat. By 1900, dairying had become important, and it is now a significant farm enterprise in the county.

The trend in the county is toward fewer, but larger, farms. Mechanization and other technological advances have made the operation of larger farms more economical. While beef-cattle farming is increasing in importance, field crops grown for the canning industry are also increasing in importance as a cashcrop enterprise.

Manufactured products are highly varied, and the electronics industries are becoming established in the county. The strongest retail lines are lumber, hardware, farm equipment, food, automobiles, and the service industries. Wholesale trade is small.

SECTION 5

PLANT OPERATION AND COSTS

WASTEWATER TREATMENT

The original facilities at the Milton wastewater treatment plant were constructed in 1939 in an abandoned gravel pit and consisted of activated sludge treatment and aerobic digestion. Prior to 1957, the effluent was passed through two rapid sand filters and discharged to dry wells to seep into the surrounding gravel. The first lagoon presently in use served as an alternate disposal point. Sand filtration was discontinued in 1957, and the single lagoon was converted to two lagoons in series.

In 1962, the original mechanical aerators were replaced with compressed air aeration, and the mechanical bar screen was replaced with a barminutor. Other additions included a blower building, primary tank bypass line, and larger capacity return sludge pumps. At about the same time, the third seepage lagoon was constructed in series with the first two lagoons. The general pattern has been to clean the bottom of the third lagoon every two years. This is accomplished by bypassing the effluent to an alternate seepage pit, allowing the third lagoon to seep dry. Material and soil are then removed by dragline and replaced with dried material excavated from the area surrounding the pit. The material removed is piled around the sides of the old gravel pit. Recently a fourth seepage lagoon has been excavated to handle any overflow from the third lagoon.

The wet sludge is hauled by truck to an area immediately north of the lagoons, where it is spread in beds and allowed to dry.

WASTEWATER CHARACTERISTICS

The wastewater is primarily domestic in nature. According to city personnel, a milk-receiving station went out of business during 1972. The only other industry is involved in reacting organic chemicals and vegetable oils to produce surfactant chemicals and emulsifiers. It initiated production during 1973 and produces an estimated 2,800 kilograms (kg) [4,000 pounds (lb)] of BOD per year. A 24-hour wastewater sample was analyzed by the State Laboratory of Hygiene in 1973 with the results shown in Table 5.

The wastewater flow is not metered; however, in 1972 a portable flow meter measured an average daily flow of 14.5 L/s (330,000 gpd) for a population of 3,900.

TABLE 5. WASTEWATER CHARACTERISTICS

Parameter	Raw Sewage	Primary Effluent	Final Effluent ^a	Final Seepage Pond	Mixed Liquor	Return Sludge ^b
BOD ₅ (mg/L)	220	200	19	16		
Soluble BOD (mg/L)			9	9.5		
Total Solids (mg/L)	910		790	745		
Fixed	580		615	595		
Volatile	330		175	150		
Suspended Solids (mg/L)	155	110	20	5	510	1,870
Fixed	35	35	5	-	70	260
Volatile	120	75	15	5	440	1,610
pH	7.3		7.6	7.5		
Soluble Solids (mg/L)	755		770	740		
Phosphorus (mg/L)						
Soluble	5.8		7.5	9.2		
Total	9.0		8.5	9.2		
Nitrogen (mg/L)						
Total Organic	14.1		4.5	2.5		
Free Ammonia	27.7		25.7	19.5		
Nitrite	0.015		0.37	0.02		
Nitrate	0.15		0.63	0.20		

Note: Results of analysis November 6-7, 1973.

^aTotal sewage flow: 12.27 L/s (280,000 gpd).

^bReturn sludge flow rate: 4.16 L/s (95,000 gpd); waste sludge flow rate: 1.14 L/s (26,000 gpd).

OPERATING COSTS

The operating costs from the City's 1977 operating budget were as follows:

Salaries (operator and other crew members for maintenance of plant and sewer line)	\$12,400
Electricity	7,400
Heating Oil	1,300
Plant Repair	1,000
Telephone	230
Misc. Supplies	1,200
Misc. Equipment	200
Sewer Line Repair	150
Total annual O & M	\$23,880

This is equivalent to an O & M cost of \$0.22/1000 gal. Based on user

charges, the estimated plant revenue was \$40,500. The original capital cost data were not available.

SECTION 6

RESEARCH METHODS

WELL CONSTRUCTION AND LOCATIONS

Well Construction

Prior to developing a plan of construction, test hole 7, well 32070, was drilled to evaluate formation conditions. Difficult drilling conditions, caving, boulders, etc., were encountered that indicated cable tool construction would be required to prevent contamination of the formation with bentonite drilling fluid. Because it was anticipated that the minimum diameter of sampling wells would be at least 10 cm (4 in) to allow sampling with a submersible pump, drilling specifications were written and bids taken on this basis. All bids received were over the budget. Additionally, the Wisconsin Department of Natural Resources would not approve the cable tool construction method as specified; it required larger holes, which would have increased the cost even more. With these limitations, the construction techniques were reevaluated and it was determined that 5 cm (2 in) wells could be constructed and sampled with a single pipe jet pump utilizing 5 cm (2 in) packers.

Several construction techniques were evaluated in the field, and the wells were ultimately constructed using small rotary rigs. The rotary construction of the smaller wells resulted in considerable savings compared to cable tool construction.

Wells were constructed with polyvinyl chloride (PVC) casing and screen to prevent any possibility of heavy metals contamination from the wells. The Department of Natural Resources concurred with PVC construction, provided the completed wells were pressure-tested to assure that there were no leaks in the casing.

The wells were constructed to prevent any contamination of the sampling zone by bentonite mud. The techniques used for each well are described below.

Wells 32170 and 32200--

These wells were constructed by rotary drilling using bentonite mud. When the desirable depth had been reached, the mud slurry was flushed out and saved. An attempt was then made to drill and jet with clear water (using jet valves on the end of the casing) below the mud cake. This was only partially successful, and these wells were used as piezometers only. Completion included gravel pack, bentonite seal above screen, and backfilling with native sand and bentonite slurry as shown in Figure 9.

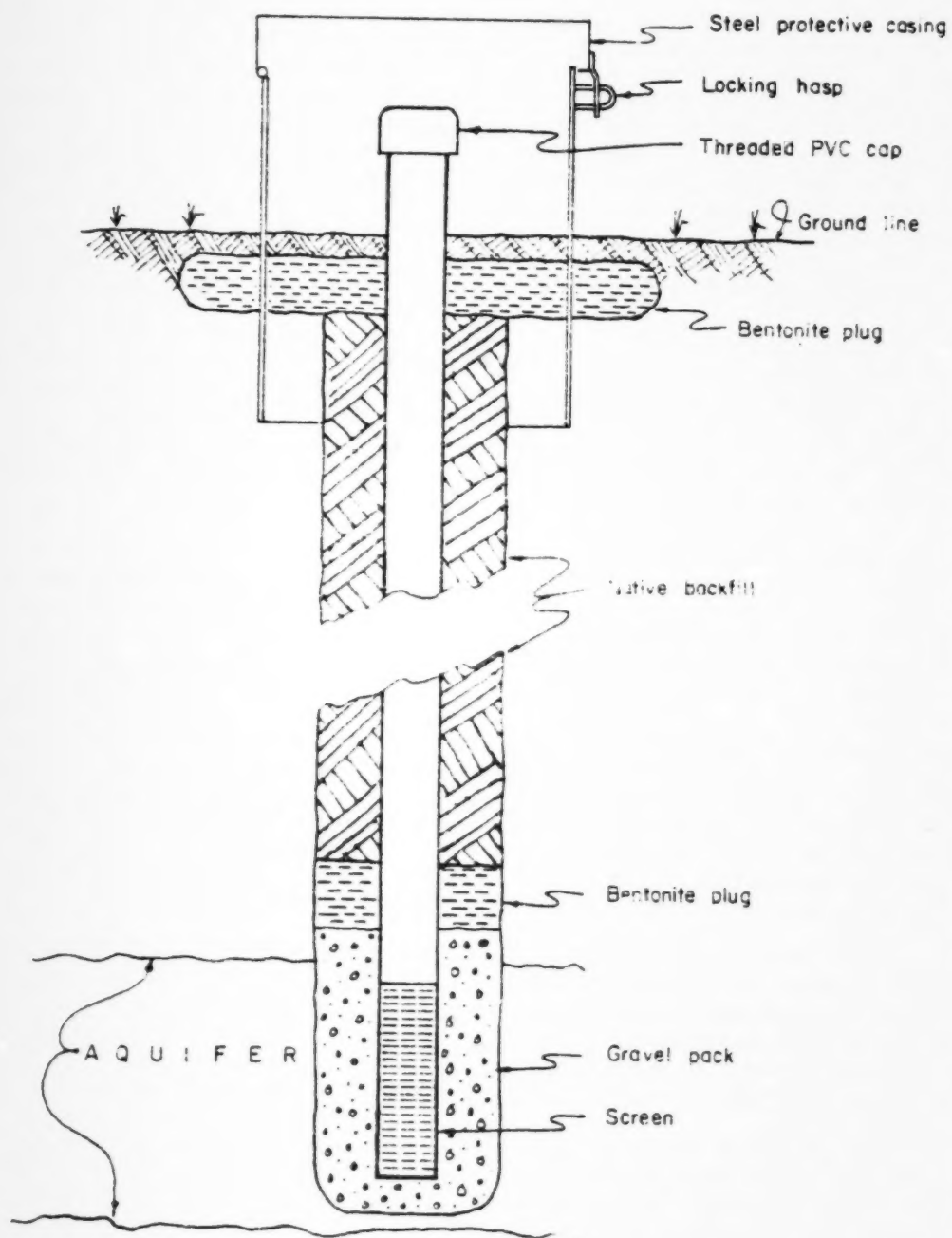


Figure 9. Typical well completion.

Wells 32010, 32020, 32060, 32110, 32120, and 32150--

Deeper wells intended to sample zones several meters below the water table were constructed in a manner similar to that described above. In addition, a temporary 10 cm (4 in) flush joint steel casing was installed to prevent caving. A 14 cm (5-5/8 in) hole was drilled using conventional rotary methods and bentonite mud to a depth just above the zone of interest. Flush joint casing was then installed, mud was flushed out and saved, and drilling proceeded with water only while driving the casing to about 3 m (10 ft) below mud cake. The casing and screen were installed, and gravel pack was added. The gravel pack was sounded to verify that it was above the screen, and a seal was placed using bentonite pellets. The mud slurry was then pumped back down. Casing was pulled and the hole backfilled using native sand and bentonite slurry. The top was sealed as shown in Figure 9.

Wells 32030, 32040, 32050, 32150, 32160, 32180, and 32190--

Wells installed to monitor the top of the water table were constructed using a 6-in hollow-stem auger. The 5-cm (2-in) casing and screen were set at the desired depth and the augers pulled. The hole was sounded to verify that natural sand had caved around the screen; then a bentonite seal was placed, and the hole was backfilled with bentonite and sand. The top was sealed as shown in Figure 9.

Wells 32080, 32090, and 32100--

It was desired to obtain water and soil samples at different depths immediately below the infiltration lagoon. Since the lagoon was continuously flooded, this was accomplished by constructing a sand berm in the lagoon and constructing wells through the built-up berm. A hollow-stem auger was used initially for the first 2 to 6 m (7 to 19 ft), depending on soil samples required; then 10-cm (4-in) steel casing was installed, and drilling proceeded with mud while driving the casing to within 3 m (10 ft) of the zone of interest. The drilling mud was then flushed out, and casing was drilled and driven to the desired depth. The 5-cm (2-in) PVC casing and screen were installed and sand packed while pulling the casing back about 1 m (3 ft). The sand pack was verified, a bentonite pellet seal placed, and the annulus between the two casings filled with bentonite slurry. The steel casing was left in place, and the surface was sealed with a bentonite slurry.

During the construction calcium hypochlorite (HTH) was added to the drilling water to provide at least 50 ppm chlorine in all rotary drilled wells except where it was necessary to collect soil cores for analysis. In these wells, HTH was added after the last soil sample was collected. In the augered holes, water containing HTH was added after the water table was reached in order to prevent bacterial contamination from the drilling process.

A single pipe jet pump with 5-cm (2-in) packers, which allowed the well casing to be utilized as the second pipe, was used to pump the wells after completion. Several times the volume of water lost during drilling was pumped from each well. The discharge was monitored for chlorine, and pumping was continued for some time after wells were completely clear of chlorine.

Pressure Testing--

The pump discharge was equipped with a pressure gage, and by shutting off

discharge, pressures up to 50 psi could be applied to the casing. The pump could then be shut off and the pressure maintained on the well casing. Wells were pressure-tested in this manner to verify that there were no leaks in the PVC joints. Wells in the infiltration pond were tested at 30 psi for 10 minutes with no loss in pressure. The other wells were tested at from 30 to 40 psi for three to five minutes. Only well 32200 showed leakage through the casing, and it was not used for sampling purposes.

Well Locations and Purposes

Figures 5 and 6 show the locations of all the monitoring wells and piezometers. Wells 1 through 9 were existing wells used only to determine water levels and direction of flow (Figure 5). Information regarding locations and water levels of these wells is summarized in Appendix C.

Justification for each of the piezometers and monitoring wells constructed for this project is as follows:

<u>Well No.</u>	<u>Explanation</u>
32010 & 32020	Monitoring wells to define the water quality and groundwater slope on the near upstream side.
32030 & 32040	Monitoring wells to define the groundwater slope and to monitor downstream water quality.
32050	Monitoring well immediately downstream from the infiltration lagoon and the stormwater basin. Should sample a mixture of water from the two areas.
32060	Monitoring well to define upslope water quality and to provide water level required for flow direction.
32070	Piezometer and test hole.
32080, 32090 & 32100	Monitoring wells drilled through the bottom of the infiltration lagoon to obtain samples of the percolate from progressively deeper discrete zones above the normal water table. Wells 32090 and 32100 were also used to obtain drive core samples of the sand through which the percolate moves.
32110 & 32120	Monitoring wells to sample deeper discrete zones immediately downstream from the infiltration lagoon. In conjunction with wells 32080, 32090, and 32100, allowed vertical water quality to be defined down to 27 m (90 ft).
32130, 32140 & 32150	Monitoring wells to sample progressively deeper zones under the storm runoff infiltration area and

<u>Well No.</u>	<u>Explanation</u>
	downstream from the effluent infiltration lagoon.
32160	Primarily used for installation of water level recorder. Sampled one time to obtain immediate downstream water quality.
32180 & 32190	Monitoring wells located in the most direct downstream location as determined by piezometers and other monitoring wells.
32170 & 32200	Used only as piezometers to define the water table and direction of flow.

SAMPLING

The infiltration lagoon is operated on a continuous basis. The lagoon is drained about every two years and the bottom dredged to remove the partly clogged sands. This operation was last performed in May 1975. Nearly 1½ years of continuous operation had occurred prior to the initial sampling in this study.

Effluent Samples

It was assumed that seepage from the lagoon occurs primarily through the side walls and that the water surface rises as lagoon walls become clogged with solids. Therefore, grab samples of the lagoon water were collected at 0.5 meter below the surface and along a side wall. Grab samples of infiltration lagoon water were collected during each sampling visit.

Because stratification may occur in the infiltration lagoons, a 24-hour composite effluent sample (composite of four grab samples collected during each sampling round) was obtained. Two effluent samples were collected on the last round. The stormwater infiltration basin was located immediately adjacent to the sewage infiltration lagoon, thus allowing the infiltrated stormwater to alter the groundwater chemistry. For this reason, a grab sample of stormwater was collected on each sampling visit.

During the study period, four infiltration lagoon samples, five composite effluent samples, and four stormwater samples were collected.

Groundwater Samples

There were three piezometers--wells 32070, 32170, and 32200--that were not sampled. The water level recorder well, 32160, was sampled once. The upstream control well, 31060, and an existing well, 31210, were sampled three times. The remaining wells were all sampled four times.

Soil Samples

The infiltrated wastewater does not move through typical soil horizons

but through the bottom of a pond excavated in glacial materials consisting of fine to coarse sand with some gravel layers and occasional boulders. Clay may be present in very small quantities mixed with sand or in thin layers.

Soil sampling was designed to obtain soil samples at progressive depths beneath the infiltration lagoons and at or just below the water table along the flow paths moving away from the lagoons.

Drive core samples taken at wells 32090, 32100, and 32120 provided a vertical profile through the unsaturated and saturated zones to a depth of 27 m (90 ft). Drive core samples taken at or just below the water table at wells 32090, 32120, 32050, 32160, and 32190 provided a horizontal profile along the flow data.

Control samples were taken at and below the water table at well 32060.

Sample numbers and location are summarized in Table 6.

CHEMICAL AND BIOLOGICAL ANALYSES

Samples collected in the field at the control and test sites were either analyzed at the field laboratory or returned to the laboratory in Oklahoma City, Oklahoma, for analyses. The time-critical parameters were analyzed in the field as soon as the samples were collected. For those samples designated for later laboratory analyses the standard methods for preservation relevant to the parameter to be analyzed were employed. In the following sections the methods used in the analyses of water and soil samples are presented in sequence. Field methods are discussed prior to laboratory methods. A summary is given in Table 7 of the field method changes that were made during the sampling program to overcome equipment and methodology problems.

Methods for Analyses of Water

Field Analyses--

Alkalinity (total)--Water samples were titrated with a 0.02 N sulfuric acid solution to an end point of pH 4.5. An exactly prepared 0.02 N solution of sodium carbonate was used to standardize the sulfuric acid and was used in spiking water samples (APHA, 1976).

Ammonia--Ammonia analyses were performed with the use of an ammonia electrode. A standard curve was constructed from 1000, 100, 10, 1, and 0.1 mg/L solutions of stock ammonium chloride. The samples and standards were treated identically. The electrode was immersed into the sample, and 10 N sodium hydroxide was added to raise the pH. The millivolt reading was recorded, and the ammonia concentration was determined directly from the calibration curve (Orion IM, 1975a, and Bremner, 1972).

Biochemical oxygen demand--Dissolved oxygen (DO) in water samples was determined with a DO meter prior to setting up biochemical oxygen demand (BOD₅). The meter was air-calibrated with an aneroid barometer according to manufacturer's instructions. Air calibrations were periodically checked

TABLE 6. SUMMARY OF DRIVE CORE SAMPLES AND LOCATIONS

Sample Numbers	Depth Below Ground Surface (ft)	Depth Below Bottom of Infiltration Pond (ft)	Depth Below Water Table (ft)
324101	8-10	0-2	--
324091	17-19	2-4	--
324092	19-21	4-6	--
324093	27-29	12-14	--
324094	31-33	16-18	2-5
324095	37-39	22-24	8-10
324102	52-54	44-46	23-25
324121	55-56	40-41	23-24
324122	79-80	64-65	47-49
324123	92	77	60
324051	25-30	--	3-8
324161	40-43	--	6-9
324191	44-48	--	3-7
314061	59-64	--	3-8
314062	70-73	--	14-17

against the Winkler method. The samples were diluted with aerated dilution water according to the results obtained from initial experimentation. In some samples no dilutions were required. The initial DO was measured directly in the BOD bottle. The bottles were then carefully glass-stoppered and plastic caps placed over the mouths of the bottles to prevent loss of water from the water seal. The samples were prepared in duplicate and incubated at 20° C in the dark for five days. The final DO was also measured with the probe. Samples containing chlorine were treated with sodium thiosulfate to eliminate the chlorine and then seeded with 24-hour-old domestic wastewater. Glucose-glutamic acid checks were performed to observe the efficiency of the BOD procedures (APHA, 1976).

TABLE 7. SUMMARY OF FIELD METHODS

Analysis	Sampling Trip			
	Milton I	Milton II	Milton III	Milton IV
Alkalinity (Total)	Potentiometric Titration	Potentiometric Titration	Potentiometric Titration	Potentiometric Titration
Ammonia	Probe	Probe	Probe	Probe
BOD	Probe	Probe	Probe	Probe
Chloride	Probe	Titration	Titration	Titration
Coliform (Total)	Membrane Filter	Membrane Filter	Membrane Filter	Membrane Filter
Coliform (Fecal)	Membrane Filter	Membrane Filter	Membrane Filter	Membrane Filter
Conductance	Meter	Meter	Meter	Meter
D.O.	Winkler	Winkler	Winkler	Winkler
Nitrate	Probe	Probe	Cadmium Reduction	Cadmium Reduction
Nitrogen (Kjeldahl)	Digestion & Probe	Digestion & Probe	Digestion & Probe	Digestion & Probe (Modified)
Orthophosphate (Soluble)	Single Reagent	Single Reagent	Single Reagent	Single Reagent
pH	pH Electrode	pH Electrode	pH Electrode	pH Electrode
Phosphorus (Soluble)	Filtration, Digestion, & Single Reagent	Filtration, Digestion, & Single Reagent	Filtration, Digestion, & Single Reagent	Filtration, Digestion, & Single Reagent
Phosphorus (Total)	Digestion & Single Reagent	Digestion & Single Reagent	Digestion & Single Reagent	Digestion & Single Reagent
Sulfide	Probe, No Preservative	Probe, No Preservative	Probe With Preservative	Probe With Preservative
Sulfate	Turbidimetric	Turbidimetric	Turbidimetric	Turbidimetric

Coliform (total)--Field samples were collected in sterile glass bottles. Samples were thoroughly mixed, and 1 mL was taken with a sterile pipette and passed through a 0.45 μ m Gelman filter. Beginning with sampling rounds three and four, one 50 mL sample was also run. All equipment was sterilized by immersion in boiling water. The filter was aseptically placed on a filter pad containing 2 mL Endo Broth in a 50 x 12 mm plastic petri dish. The dishes were placed into a whirlpac plastic bag, inverted, and incubated at 35^o C for 24 hours in a bacteriological incubator. The typical coliform colonies counted had a pink to dark red color with metallic surface sheen (APHA, 1976).

Coliform (fecal)--The procedure was identical to that for total coliforms with the exception of medium. The medium used was mFC, and plates were not inverted. Plates were incubated at 44.5^o C for 24 hours. Typical coliform colonies were small and blue (APHA, 1976).

Conductivity--Determination of specific conductance was performed using a conductivity meter. Using a potassium chloride solution of known conductance, the meter was calibrated prior to running analyses. Specific conductance values were corrected to 25^o C by using multiplication factors (APHA, 1971).

Dissolved oxygen--At the well site, immediately after pumping the well, dissolved oxygen was measured by the azide modification of the Winkler method. One Hach powder pillow each of manganous sulfate, alkaline-iodide-azide, and sulfamic acid was added to the water sample. The sample was then brought to the field laboratory and titrated with phenylarsine oxide (PAO) using a starch indicator (APHA, 1976).

Nitrate nitrogen--Samples from round one were analyzed for nitrate with the use of the nitrate electrode. The probe was immersed in the sample and the final millivolt reading was recorded. Nitrate concentrations were determined from a standard curve prepared from standards serially diluted from a potassium nitrate stock solution.

Due to the inability to recover spikes and uncontrolled drift in millivolt readings in certain samples, the nitrate probe was replaced with the cadmium reduction column method for sampling rounds three and four. The samples were flocculated and/or filtered through a 0.45 μ m Gelman filter prior to analyses. An aliquot of sample was passed through a column containing granulated copper-cadmium to reduce nitrate to nitrite. Columns were reactivated between field trips and at other times when efficiency dropped. The nitrite (that originally present plus reduced nitrate) was reacted with the color reagent to form a highly colored azo dye, which was measured spectrophotometrically at 420 nanometers (nm). The nitrite was then determined in the sample and subtracted from the initial value to obtain nitrate (USEPA, 1974; Orion IM, 1975b; and Orion IM, 1976c).

Nitrogen (total and soluble organic)--A micro-Kjeldahl digester and an ammonia electrode were used for analyses. Procedural changes were made throughout the field trips in an attempt to correct the problem of not obtaining total nitrogen recovery. A 50 mL aliquot of sample (filtered for soluble,

not filtered for total) was boiled in the presence of concentrated sulfuric acid, potassium sulfate, and mercuric sulfate, and evaporated one-half hour past the disappearance of sulfurous acid fumes. Rounds one, two, and three samples were analyzed by adding 10 N sodium hydroxide to the sample and recording the millivolt reading from the ammonia probe. For the first three rounds, the mercury interference in the digestion reagent was not identified before testing for ammonia. This resulted in an ammonia-mercury complex formation and low nitrogen results. Experiments in the laboratory showed that addition of 2 N sodium iodide with the 10 N sodium hydroxide did not effectively eliminate the mercury interference. Beginning with round four, two major changes were made: 1) Hengar crystals, which are selenium coated, replaced mercury as the catalyst and 2) samples were partially neutralized with sodium hydroxide and allowed to cool in an ice bath prior to ammonia analyses to compensate for heat gained from addition of the sodium hydroxide to acid. Excellent results were obtained, using the final revised procedures (Orion IM, 1975a, and Bremner, 1972).

Orthophosphate (soluble)--Orthophosphate phosphorus was determined by the single reagent method. Samples were filtered through a 0.45 μ m Gelman filter. The pH of the sample was adjusted to 7.0 ± 0.2 with sodium hydroxide. Ammonium molybdate, antimony potassium tartrate, and ascorbic acid color reagent were added to the sample and read in the manner described for total phosphorus (USEPA, 1974).

pH--The pH was determined by use of a glass combination electrode. The meter was calibrated for pH determinations by using buffers of pH 4, 7, and 10 (APHA, 1976).

Phosphorus (total)--Phosphorus was determined by the single reagent method. Sulfuric acid (11 N) and ammonium persulfate were added to the samples. Samples were boiled gently followed by pH adjustment to $pH\ 7.0 \pm 0.2$ with sodium hydroxide. Ammonium molybdate, antimony potassium tartrate, and ascorbic acid color reagent were added to the samples. The blue color formed was read at 640 nm using a spectrophotometer. The phosphorus concentration was determined from a standard curve that was prepared from serial dilutions made from a stock phosphorus solution (USEPA, 1974).

Sulfide sulfur--Analyses for sulfide were made with a sulfide electrode. Procedural changes involving sulfide anti-oxidant buffer (SAOB) and standards were a result of additional research by Orion (Orion IM, 1976a).

Samples for rounds one and two were brought to the field laboratory, where an aliquot of sample was added to an equal volume of 50 percent SAOB. The SAOB contained sodium hydroxide, sodium salicylate, and ascorbic acid. The calibration curve was prepared from a standard consisting of sodium sulfide, sodium hydroxide, sodium salicylate, and ascorbic acid. The standard was titrated against a 0.1 M lead perchlorate solution to obtain the exact normality. Standards and samples were treated identically except standards were prepared by diluting in 25 percent SAOB. The electrodes were immersed in the sample, and the millivolt reading was recorded after it stabilized. The exact concentration of sulfide was determined from the standard curve (Orion IM, 1975c).

Samples for rounds three and four were added directly to plastic bottles half filled with 50 percent SAOB in the field. The SAOB contained sodium hydroxide, disodium ethylenediaminetetraacetic acid (EDTA), and ascorbic acid. The calibration curve was prepared from a standard consisting of sodium sulfide and SAOB. The standard was titrated against 0.1 M lead perchlorate to find the exact normality of the standard. This solution was then serially diluted to prepare a standard curve. The samples and standards were treated identically. The electrodes were immersed in the sample, and millivolt readings were recorded. The exact concentration of sulfide was determined from the standard curve (Orion IM, 1976a).

Laboratory Analyses--

Boron--Boron was analyzed by the curcumin method. Samples were added to evaporating dishes made of boron-free glass. Curcumin reagent was added, and the dishes were placed in a water bath set at $55 \pm 2^\circ \text{C}$ and evaporated to dryness. The contents of each dish were redissolved in 95 percent ethyl alcohol, filtered through Whatman 30 filter paper, and read at 540 nm on a spectrophotometer. The boron concentration was determined from a standard curve, which was prepared from standards serially diluted from a 100 mg/L boron stock solution (APHA, 1976).

Chemical oxygen demand--Samples were collected in plastic bottles containing sulfuric acid as a preservative and kept on ice until the analyses were completed. The dichromate reflux method was used for chemical oxygen demand (COD) determinations. The alternate procedure for dilute samples in which the potassium dichromate and ferrous ammonium sulfate are more dilute was used for low level COD samples (USEPA, 1974).

Chloride--Analyses for chlorides for the first round were performed with a chloride electrode. Due to problems with this electrode, sample analyses of rounds two, three, and four were completed by the mercuric nitrate titration method. Hach powder pillows (prepared indicator-acidifier reagent) were used as the indicator for rounds two and three, but the indicator-acidifier reagent was used for round four (APHA, 1971).

Prior to running analyses with a chloride electrode, standard curves were prepared from serially diluted standards of a 100 mg/L sodium chloride stock solution. Standards and samples were treated identically. The electrodes were immersed in samples with ionic strength adjuster (ISA) added. Samples were mixed at a constant rate on a magnetic stirrer until stable millivolt readings were observed. Using millivolt readings, unknown concentrations were determined from the calibration curve (Orion IM, 1976b).

Samples for titration were adjusted to a pH of 2.5 with nitric acid, and indicator-acidifier reagent was added to the sample, which was then titrated with 0.0141 N mercuric nitrate. If high chlorides were present, 0.141 N mercuric nitrate was used as the titrant. The samples were titrated to a light purple end point. Iron, which acts as an interference, was removed from the sample through flocculation with zinc sulfate solution and sodium hydroxide. The floc was allowed to settle and was filtered through a 0.45 micron filter. Analyses were performed on the filtrate (APHA, 1976).

Herbicides--Field samples were collected in hexane-rinsed, glass-stoppered bottles. Chlorinated phenoxy acid herbicides were extracted from the acidified water sample with diethyl ether. The ether layer was filtered through anhydrous sodium sulfate into hexane-rinsed bottles, 37 percent potassium hydroxide was added, and the sample was returned to the laboratory for analyses. Water was added to the sample and the ether removed by evaporation. Extraneous organic matter was removed by extracting the basic aqueous phase with diethyl ether. The aqueous phase was acidified to hydrolyze the esters to acids and the acids extracted with diethyl ether. Benzene was added and the solution evaporated to 0.5 mL in Kuderna-Danish evaporators.

The acids were esterified to methyl esters with 0.5 mL boron trifluoride in methanol. The benzene layer was shaken with neutral 5 percent sodium sulfate solution. The benzene extracts were further purified by passing through Florisil columns. Identification and quantification of the esters were made by gas-liquid chromatography and were corroborated through the use of two or more unlike columns (USEPA, 1971).

Metals (total)--Metal analyses were performed by atomic absorption spectrophotometry. Field samples were collected in plastic bottles and preserved with nitric acid to a pH 2. Two bottles were preserved for each sample. Round four samples were filtered at the well site through a 1 μ m filter. All metals except for arsenic, selenium, and mercury were prepared by cautiously digesting with nitric acid and evaporating to dryness. Samples were refluxed with nitric acid and brought back to volume, then subjected to the standard conditions and instrumental parameters for the corresponding metals (USEPA, 1974; Martin, 1975; and Atomic Absorption Methods Manual, 1975).

Mercury was analyzed by the cold vapor technique. Concentrated sulfuric acid, concentrated nitric acid, 5 percent potassium permanganate, and potassium persulfate were added, and samples were heated 2 hours at 95° C in a water bath. Sodium chloride and hydroxylamine hydrochloride were added to samples. The mercury was vaporized by adding stannous sulfate (USEPA, 1974).

Arsenic and selenium were determined by atomic absorption, using a heated graphite atomizer and electrodeless discharge lamps. The samples were digested with nitric acid and hydrogen peroxide. Nickel nitrate was added to the digested samples prior to analysis (Martin, 1975).

Organic carbon (total and soluble)--Soluble organic carbon samples were filtered through a 0.45 micron Gelman filter and kept iced until prepared for analyses. Total organic carbon samples were not filtered. Purging and sealing of the ampules were done in the field. Ten mL glass ampules were prepared by adding 0.2 g potassium persulfate to 5 mL of sample and 0.5 mL of 3 percent phosphoric acid. Samples were then purged with oxygen. Phosphoric acid was prepared daily and added to the ampules just prior to sealing. Samples were prepared in triplicate. Carbon dioxide-free water was used for the blanks. Tests were performed in the laboratory to determine optimum length of time for purging and combusting the samples. The organic matter in the ampules was oxidized in a pressure vessel that was placed in an oven heated to 175° C for 16 hours.

After oxidation, the samples were analyzed with a carbon analyzer (USEPA, 1974, and Oceanography International IM, 1971).

Pesticides--Field samples were collected in hexane-rinsed, glass-stoppered bottles. Organochlorine pesticides were extracted from the water with an 85:15, hexane: methylene chloride solvent mixture in the field. The organic layer was filtered through anhydrous sodium sulfate into hexane-rinsed bottles and returned to the laboratory for analysis. The organochlorine pesticides analyzed were endrin, lindane, methoxychlor, and toxaphene. Extracted samples were concentrated in Kuderna-Danish evaporators in a hot water bath. The concentrated samples were purified, if necessary, by passing through Florisil columns. Identification and quantification of pesticides were made by gas-liquid chromatography and were corroborated through the use of two or more unlike columns (USEPA, 1971).

Solids (dissolved)--Samples were brought to room temperature, and well-mixed aliquots were passed through Reeve Angel, type 934 AH filters with gentle suction. One hundred mL was transferred quantitatively to pre-weighed evaporating dishes. Samples were evaporated to dryness at 100° C in a water bath and placed in an oven at 180° C for 1½ to 2 hours. Evaporating dishes were weighed again after cooling in a desiccator (USEPA, 1974).

Solids (suspended)--Samples were brought to room temperature and mixed thoroughly. Using gentle suction, 50 mL of sample was filtered through Reeve Angel, type 934 AH filters in 25 mL tared Gooch crucibles. The filtered samples were dried in an oven at 104° C for one to two hours. Crucibles and filters were desiccated until cool and reweighed (USEPA, 1974).

Solids (total)--Data for total solids were obtained by summing the dissolved and suspended solids values.

Solids (volatile suspended)--The solids retained on the filter from the suspended solids analysis were ignited at 550° C in a muffle furnace to determine volatile suspended solids (USEPA, 1974).

Sulfate sulfur--Sulfates were analyzed turbidimetrically by the barium sulfate method. While the solution was being stirred, conditioning reagent and barium chloride crystals were added. After exactly one minute, the barium sulfate turbidity was read at 420 nm on a spectrophotometer, and the sulfate concentration was calculated from a standard curve prepared from serially diluted standards of a 1,000 mg/L sodium sulfate stock solution (APHA, 1976).

Methods for Analyses of Soils

Laboratory Analyses--

Cation exchange capacity--Air-dried soil samples (<2 mm particle size) and 1 N ammonium acetate were shaken for several minutes and allowed to stand overnight. Sample extracts were filtered through perforated Coors crucibles containing Reeve Angel glass fiber filters using gentle suction. Soil leaching was done with 1 N ammonium acetate, adding small amounts at a time so

that leaching took no less than one hour. This was followed by leaching with 95 percent ethanol in small amounts until the leachate gave a negative test for ammonia with Nessler's reagent. The soil was air-dried and weighed. Water was added, and ammonia was measured with an ammonia electrode by immersing into the sample and adding 10 N sodium hydroxide to raise the pH. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of 1,000 mg/L ammonium chloride stock solution. No modifications were made for calcareous soils (Orion IM, 1975a; Busenberg, 1973; and Black, 1965).

Boron--Air-dried soil samples were refluxed with distilled water for 30 minutes. The soil-water suspension was separated by adding 1 N calcium chloride and centrifuging at 2,000 rpm for 10 minutes. The boron concentration of the supernatant was determined by the curcumin method (APHA, 1976, and Black, 1965).

Herbicides--Air-dried soil samples were mixed with water, sulfuric acid, and diethyl ether. After shaking for four hours, the extracts were filtered through anhydrous sodium sulfate. An aliquot of the ether extract was transferred to a separatory funnel and shaken with sodium hydroxide. The aqueous phase was transferred to another separatory funnel, the pH adjusted to 3, and extracted with ether. Mineral oil in hexane was added to the extract and evaporated carefully to 5 mL, employing a 50°C water bath and a Snyder column. The extract was further evaporated to 0.1 mL. The phenoxy acids were esterified using boron trifluoride in methanol, as described for herbicides in water (Woodham, 1971).

Metals (exchangeable and extractable)--Air-dried soil was pulverized by mortar and pestle to pass a 2 mm screen.

Aluminum was extracted with 1 N potassium chloride. The suspension was filtered immediately, and the solids were washed with 1 N potassium chloride (Ellis, 1975). Aluminum was analyzed by atomic absorption.

The ions K, Mg, and Na were exchanged with 1 N ammonium acetate by shaking for five minutes. Extracts were filtered through Whatman No. 40 filter paper and analyzed by atomic absorption (Ellis, 1975).

The metals Fe, Zn, Mn, Cu, Ni, Pb, Cr, and Co were extracted from soils by shaking for two hours with triethanolamine, calcium chloride, and carboxymethylimino bis-ethylenitrilo-tetraacetic acid (DTPA) (10 mL per 4 g soil), followed by filtering through Whatman No. 42 filter paper (Ellis, 1975). The metals were analyzed by atomic absorption.

Metals (total)--Samples were prepared by digesting soil in teflon beakers with hydrofluoric acid and evaporating the liquid to dryness. This was followed by digesting with a 3:1 hydrochloric: nitric acid mixture (aqua regia) for five minutes and then redissolving any residue in 1:1 hydrochloric acid. Samples were filtered and analyzed by atomic absorption spectrophotometry.

Total mercury analyses were prepared by digesting soils with aqua regia

for two minutes in a 95⁰ C water bath, followed by a 5 percent potassium permanganate digestion for 30 minutes. Sodium chloride, hydroxylamine hydrochloride, and distilled water were mixed with the sample and stannous sulfate was added to vaporize the mercury through the absorption cell (USEPA, 1974).

Total arsenic and selenium analyses were prepared by refluxing the soil samples two times with nitric acid, followed by digestion with hydrogen peroxide and nitric acid. Nickel nitrate was added to the digested samples prior to analyses by atomic absorption, using the heated graphite atomizer and electrodeless discharge lamps.

Nitrogen (inorganic)--Because ammonia, nitrate, and nitrite nitrogen readily change form in soil, these parameters were summed to obtain inorganic nitrogen values. Ammonia, nitrate, and nitrite nitrogen were determined by the following methods:

Ammonia nitrogen was determined after extracting air-dried soil with 2 N potassium chloride by shaking on a rotary shaker for two hours. Samples were allowed to sit for 30 minutes before being analyzed for ammonia with an ammonia electrode. The probe was immersed in the sample, followed by the addition of sodium hydroxide to raise the pH. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution (Orion, IM, 1975a, and Black, 1965).

For the nitrate and nitrite nitrogen determination, potassium chloride (2 N) was used to extract the ammonia, nitrate, and nitrite from the air-dried soil by shaking together for one hour. The suspension was filtered through Whatman No. 4 filter paper. The pH was adjusted between 11 and 14 with 10 N sodium hydroxide. At least half the volume of the filtrate was evaporated by boiling, to drive off all ammonia nitrogen. After cooling and adjusting the filtrate to the original volume, concentrated sulfuric acid and Devarda's alloy were added. Samples were placed in a 70⁰ C water bath for two hours for reduction of nitrate and nitrite to ammonia. Ammonia concentrations of the solutions were measured with an ammonia electrode after addition of sodium hydroxide. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution (Orion IM, 1975b; Orion IM, 1976c; and Black, 1965).

Nitrogen (organic)--Air-dried soil was digested with concentrated sulfuric acid, potassium sulfate, cupric sulfate, and selenium. The solutions were evaporated for 30 minutes past the disappearance of sulfurous acid fumes. Samples were diluted, neutralized with sodium hydroxide, and analyzed with an ammonia electrode. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution (Orion IM, 1975a; Bremner, 1972; and Black, 1965).

Pesticides--Soil samples were air-dried, mixed with Celite, and Soxhlet extracted for 12 hours with hexane: acetone (41:59 v/v). The extracts were then shaken in a separatory funnel with a saturated sodium chloride

solution and extracted with hexane. The extracts were washed twice with a saturated sodium chloride solution. The hexane phase was dried with anhydrous sodium sulfate. Unless further purification was necessary, the samples were ready for gas chromatographic analyses (Williams, 1968).

pH--The soil was air-dried and pulverized by mortar and pestle before samples were analyzed. Twenty-five mL of distilled water per gram of soil was added and the mixture stirred. The hydrogen ion concentration (pH) was measured while the sample was mixing (Black, 1965).

Phosphorus (available)--Samples of air-dried soil were extracted with 0.03 N ammonium fluoride and 0.025 N hydrochloric acid by shaking for one minute. The extract was filtered through Whatman No. 42 filter paper and the pH adjusted to 7.0 ± 0.2 with sodium hydroxide. Color reagent (mixture of antimony potassium tartrate, ammonium molybdate, and ascorbic acid) was added, and the absorbance was read at 640 nm with a spectrophotometer (APHA, 1976, and Black, 1965).

Phosphorus (total)--Air-dried soil samples were digested with 6 percent perchloric acid in a flask. Samples were boiled until the dark color due to organic matter disappeared. An aliquot was adjusted to $pH\ 7.0 \pm 0.2$ with sodium hydroxide, followed by the addition of color reagent. After color development, absorbance was measured on a spectrophotometer at 640 nm (APHA, 1976, and Black, 1965).

Sulfur (total)--Sulfate sulfur and organic sulfur were combined to obtain total sulfur values.

For the determination of sulfate sulfur, monobasic calcium phosphate was added to air-dried soil samples and shaken for 12 hours, followed by filtering through a Gooch crucible fitted with a glass fiber filter. An aliquot of filtrate, gum acacia solution, and hydrochloric acid was mixed with barium chloride crystals. Absorbance was measured at 420 nm on a spectrophotometer. The concentration of sulfur in the samples was determined from a standard curve prepared from serially diluted standards of a stock sulfate solution (Black, 1965).

The residue in the Gooch crucible from the sulfate sulfur determination was used for organic sulfur analyses. After drying at $103^{\circ}C$, sodium bicarbonate was mixed with the soil and added uniformly as a surface layer. After ignition at $500^{\circ}C$ for three hours the sample was extracted and analyzed as described for sulfate sulfur (Black, 1965).

Methodology Problems and Modifications

As indicated previously, certain difficulties in analyses were experienced in using the standard methods. The following sections discuss the problems encountered in the water and soil analyses and indicate the modifications that were employed in an attempt to obtain measurements of the parameters involved in the study. Table 7 summarized the modifications for field methods for each of the sampling rounds during the study.

The problems and modifications are mentioned for two reasons. First, for time-critical parameters, it may be the explanation for missing data for certain samples. If the method was known to be faulty, the data were deleted from the data tabulation shown in Appendix B. Second, certain analytical procedures were modified to obtain accurate results for the types of samples encountered in this study. These modifications are reported for the benefit of future investigators for similar type studies. Also, it was deemed valuable to report those cases when certain new analytical tools did not conform to the manufacturer's claims.

Water Analyses--

Calcium--Initial review of calcium data indicated low values were being generated. Spiked samples indicated low recoveries. Therefore, all samples were repeated and were run by the method of standard addition. Excellent recoveries were obtained; therefore, all calcium data are valid.

Chemical oxygen demand--Results from some of the early field samples stimulated questions concerning the procedure being used. Extensive spiking and duplication of samples showed no methodology problems and no reason for the anomalous data.

Chloride--The initial problem was a faulty electrode. Later problems involved matrix interferences. The probe method was replaced by mercuric nitrate titrations as listed in the EPA methods manual (USEPA, 1974).

Metals--Data from several metals appeared anomalous at some time during the analyses. A malfunctioning atomic absorption (AA) was initially a problem. Failures included several faulty hollow cathode lamps, a faulty printed circuit board in the photomultiplier, an out-of-tolerance nebulizer, and numerous graphite rods (cuvettes) that had been manufactured without meeting specifications. Analyses in question were repeated, using an operational instrument. All metal analyses reported are considered valid data.

Nitrate nitrogen--The nitrate probe was used according to the manufacturer's directions with success for some samples, but problems were encountered with other samples. Discussions with the manufacturer resulted in new filling solutions for the probe and different ionic strength adjuster solutions to aid in reducing interferences. Some faulty probes were also discovered during the analyses. Although the probe method was abandoned during round two sampling, nitrate values obtained by the probe were comparable to Cd reduction method values, and data were thus considered valid.

Organic nitrogen--The EPA method was modified initially by using the ammonia probe instead of distilling the ammonia and titrating. It was discovered later that the temperature of the solutions measured with the electrode varied markedly, depending on the amount of acid in the solutions. This temperature variation affected the probe adversely; thus, it was found necessary to partially neutralize samples to about pH 5, cool to room temperature, then add the remainder of the base and measure the ammonia with the probe. Several items concealed this problem initially. Three electrode failures were experienced, and thus questionable data were attributed to this. It was also discovered that mercuric ions in the digesting reagent

were not releasing the ammonium during analyses.

Soil Analyses--

Inorganic nitrogen--Nitrate + nitrite nitrogen was determined initially according to the ASOA method, with the exception that steam distillation of ammonia was replaced by the use of the ammonia probe. Spiked samples indicated that reduction of nitrate and nitrite was limited and that the method was underestimating the concentrations of nitrate and nitrite nitrogen. After much experimentation, it was discovered that the Devarda alloy would not reduce NO_3^- and NO_2^- to NH_4^+ without the addition of a proton donor. Satisfactory results were obtained by adding small amounts (<1 mL) of concentrated H_2SO_4 .

Organic nitrogen (total)--The method as described by Bremner and Tabatabai (1972) was followed initially. The temperature interference described for the organic nitrogen procedure for water samples was initially a problem for soil samples. Partial neutralization followed by cooling solved the difficulty of obtaining accurate results.

DATA EVALUATION PLAN

General background data about the site including geology, hydrogeology, soils, climate, and other relevant information have previously been presented.

Data collected at the field site from wells, effluent samples, and soils were transmitted to the laboratory for collation and computer tabulation. Additional analytical procedures at the laboratory provided data on many parameters, which were integrated with field data. Appendix B provides complete data tables for all parameters that had reliable, internally consistent results. In some instances columns of data were combined, such as ammonium and nitrate-nitrite nitrogen, if analytical procedures indicated that individual parameters might overlap.

In the Results and Discussion section the critical resource values of water and soils are compared for the test and control sites.

The evaluation of the results of water analyses is presented in three parts: effluent, surface runoff, and groundwater. In each part the results are discussed in relation to such site characteristics as hydrology, renovation performance of the soil, or quality of the groundwater. In addition, some projections are attempted for long-term loadings of critical parameters contained in the wastewater.

For soils the results that merited discussion include P, N, and selected heavy metals. Although values were obtained for many other parameters, the differences between control and test sites were generally within the range of variability expected for any one soil site.

Finally, the possible adverse health effects associated with fecal and total coliform bacteria were investigated in water samples.

SECTION 7

RESULTS AND DISCUSSION

Samples collected in the field were identified by a code number that was used on all data tables and graphs as well as in the narrative sections where individual sample results are discussed. The wells at the Milton site were coded according to a five-digit number. The first digit (3) referred to the Milton site; the second digit indicated whether the sample was from a control (1) or test (2) site; the third and fourth digits indicated the sample well number (01 to 20); the fifth digit was always 0.

The well water samples were numbered using a six-digit code. The first four digits indicated the well and location, while the last two digits indicated the sampling round--first digit: 3 - Milton; second digit: 1 - control site wells, 2 - test site wells; third and fourth digits: 01 to 20 - well numbers, 21 - existing domestic well, 44 - stormwater basin, 45 - effluent infiltration lagoon, 46 - treatment plant effluent, 60 - municipal water; fifth and sixth digits: 01 - sample collected first round (October 5-7, 1976), 02 - sample collected second round (November 15-17, 1976), 03 - sample collected third round (April 7-10, 1977), 04 - sample collected fourth round (June 21-23, 1977).

Soil samples were similarly coded except that the third digit was always 4, indicating drive core samples. The fourth and fifth digits indicated the well location where samples were taken, and the sixth digit indicated the relative sampling depth (Appendix B).

WATER

General

The Milton wastewater treatment plant produced an effluent for introduction into the infiltration lagoons that was typical of a secondary effluent. Laboratory analyses of the effluent were run in October and November, 1976, and in April and June, 1977, in an attempt to look for seasonal effects. The results are summarized in Table 8 for effluent sample numbers 324601 through 324604. Also presented in Table 8 are mean values and ranges, determined statistically using the pooled variances method, of other water samples taken at the same time as the effluent samples. This table allows for comparison of water samples from infiltration and stormwater lagoons, the municipal water supply, and groundwater with those from the treatment plant effluent. Of the groundwater sampled, only the test site was affected by treatment plant effluent infiltration and stormwater. Specific sample numbers are given below:

TABLE 8. SUMMARY OF CONSTITUENT CONCENTRATIONS IN TREATMENT PLANT EFFLUENT, MUNICIPAL WATER SUPPLY, INFILTRATION WATER, AND GROUNDWATER (mg/L unless noted)

Parameter	Treatment Plant Effluent		Infiltration Lagoon		Stormwater Lagoon		Municipal Supply		Control Groundwater		Test Groundwater		
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Dissolved Oxygen	3.4-4.0	3.7 ^a	1.4-22.6	9.8	8.2-16.1	12 ^r	4.3-4.4	4.4	3.2-9.4	7.0	<0.1-3.6	1.3	
pH (units)	7.5-8.0	7.7	7.6-8.9	8.1	7.4-9.4	8.3	7.6-8.0	7.8	7.6-7.9	7.7	7.2-7.8	7.5	
Conductivity (umhos/cm)	1312-1596	1431 ^a	1307-1509	1407 ^a	139-255	197 ^r	523-655	589	559-769	677	1176-1584	1278	
Total Alkalinity	382-428	410 ^a	372-448	407 ^a	32-96	64 ^r	276-304	290	216-360	282	265-501	405	
Dissolved Solids	608-866	728 ^a	568-805	721 ^a	114-258	154 ^r	329-347	338	359-472	405	418-793	688	
Suspended Solids	11-45	29	16-33	25	5-28	17	2	2					
Total Solids	630-911	757	684-838	771	123-283	171 ^r	331	331					
Volatile Suspended Solids	7-36	21	4-12	9	5-18	11							
Biochemical Oxygen Demand	12.0-52.0	28.0	5.0-39.0	23.0 ^a	6.0-18.0	12.0	<1.0	<0.1	<0.1-16.0	3.9	<1.0-19.0	4.2	
Chemical Oxygen Demand	48-112	84 ^a	49-82	63 ^a	28-97	53	6-12	9	3-37	18.4	10-199	32	
Chloride	164-235	200 ^a	173-227	188 ^a	4-50	22 ^r	3-6	5	12-39	23	34-216	149	
Sulfide-S	<0.1	0.1 ^b	<0.1	0.1 ^b	<0.1	0.1 ^b			<0.1	0.1 ^b	0.1-1.6	0.1 ^b	
Total Coliform (#/100 ml)	0-TNTC ^c	TNTC	0-TNTC	TNTC	0-TNTC	TNTC			0-100	17	0-TNTC	TNTC	
Fecal Coliform (#/100 ml)	0-TNTC	TNTC	0-TNTC	TNTC	0-TNTC	TNTC			0	0	0-7707	258	
Total Organic C	20-61	36	13-108	49	13-43	31							
Dissolved Organic C	13.0-50.0	28.0	8.0-55.0	27.0	12.0-27.0	19.0	1.3	1.3	4.0-15.0	11.0	3.0-66.0	16.0	
Total Organic N	<0.1-12.0	6.5	<0.1-5.3	3.4	<0.1-1.0	0.5			<0.2	<0.1-1.0	<0.1-7.0	1.0	
Soluble Organic N	<0.1-3.8	1.3	<0.1-4.2	1.1	0.1-2.0	0.8	<0.1-0.2	<0.2	0.1-0.6	0.2	0.1-35.4	13.7	
Ammonium-N	10.0-25.6	19.0 ^a	13.3-30.2	19.2 ^a	<0.1-0.8	0.3 ^r	<0.1-0.2	1.1	4.3-9.6	6.7	<0.1-10.3	1.5	
Nitrate-N	1.0-12.6	5.3	1.0-10.0	3.7	<0.1-2.6	1.3	0.5-1.7	1.1					
Total Phosphorus	7.1-9.5	8.2	1.0-7.5	5.4	0.09-4.0	2.03 ^r			<0.03	<0.01-0.24	0.08	0.04-14.0	4.0
Soluble Phosphorus	6.4-8.5	7.8 ^a	0.9-6.8	4.8 ^a	0.07-3.9	1.9 ^r							
Soluble Orthophosphate	6.0-8.0	7.0 ^a	0.80-6.3	4.2 ^a	<0.01-3.3	1.6 ^r	<0.01-0.03	<0.02	<0.01-0.20	0.05	0.03-12.0	3.8	
Sulfate	48-54	51 ^a	58-61	59 ^a	5-17	11 ^r	19-25	22	35-50	43	9-75	35	

(continued)

TABLE 8. (continued)

Parameter	Treatment Plant Effluent		Infiltration Lagoon		Stormwater Lagoon		Municipal Supply		Control Groundwater		Test Groundwater	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Aluminum	<0.1-0.4	0.3 ^b	<0.1-0.4	0.3 ^b	<0.3-1.0	1.0 ^b	<0.2	<0.2	<0.1-1.5	1.0 ^b	<0.3-3.5	1.0 ^b
Arsenic ($\mu\text{g/L}$)	<10-18	11	<10-14	7	<10	5	<10	<10	<10	5	<10-53	24
Boron ($\mu\text{g/L}$)	597-823	681 ^a	475-897	625 ^a	38-256	139 ^r	68	68	49-395	248	180-937	504
Cadmium ($\mu\text{g/L}$)	<20	20 ^b	<20	20 ^b	<20	20 ^b	<20	20 ^b	<20	20 ^b	<20	20 ^b
Calcium	58-75	70	54-80	64	5-23	13 ^r	67-76	72	57-132	84	21-129	70
Cobalt ($\mu\text{g/L}$)	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b
Chromium ($\mu\text{g/L}$)	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b	<20-50	50 ^b
Copper ($\mu\text{g/L}$)	<20-100	100 ^b	<20-100	100 ^b	<20-100	100 ^b	30-100	100 ^b	<20-135	100 ^b	<20-176	100 ^b
Iron	<0.2-0.5	0.5 ^b	<0.1-0.5	0.5 ^b	<0.2-1.1	0.5 ^b	<0.1-0.5	0.5 ^b	<0.1-1.2	0.5 ^b	<0.1-3.6	1.5
Lead ($\mu\text{g/L}$)	<100-200	200 ^b	<100-200	200 ^b	<100-200	200 ^b	<100-200	200 ^b	<100-200	200 ^b	<100-200	200 ^b
Magnesium	35-40	37	33-40	36	1-6	4 ^r	33-36	35	30-46	37	31-83	38
Manganese	<0.05-0.10	0.10 ^b	<0.05-0.10	0.10 ^b	<0.05-0.10	0.10 ^b	<0.05-0.10	0.10 ^b	<0.05-0.10	0.10 ^b	0.09-2.50	0.60
Mercury ($\mu\text{g/L}$)	<0.5-2.0	1.0 ^b	0.6-2.0	1.0 ^b	<0.5-2.0	1.0 ^b	<0.5-1.0	1.0 ^b	<0.5-2.0	1.0 ^b	<0.5-2.0	1.0 ^b
Nickel ($\mu\text{g/L}$)	<50-200	100 ^b	<50-100	100 ^b	<50-100	100 ^b	<50-100	100 ^b	<50-100	100 ^b	<50-100	100 ^b
Potassium	9.1-16.0	14.0 ^a	9.1-16.4	14.4 ^a	1.8-5.3	4.2 ^r	<1.0-1.7	<1.4	<0.9-2.8	2.1	5-17	12
Sodium	102-212	147 ^a	105-181	150 ^a	9-29	17 ^r	4-5	5	3-25	9	39-177	121
Zinc ($\mu\text{g/L}$)	<20-242	78	<20-50	50 ^b	<20-50	50 ^b	20-50	50 ^b	<20-2700	628	<20-2260	191
Selenium ($\mu\text{g/L}$)	<10-26	12	<10	5	<10	5	<10	<10	<10	5	<10	10 ^b
Endrin (ng/L)	<0.03	0.03 ^b	<0.03	0.03 ^b	<0.03	0.03 ^b	<0.03	0.03 ^b	<0.03	0.03 ^b	<0.03	0.03 ^b
Lindane (ng/L)	14.7-108.0	41.0	3.0-159.0	44.0	1.0-124.0	35.6	<0.2-0.5	<0.4	<0.2-20.7	7.4	<0.2-1360.0	91.7
Methoxychlor (ng/L)	<0.01	0.01 ^b	<0.01	0.01 ^b	<0.01	0.01 ^b	<0.01	0.01 ^b	<0.01	0.01 ^b	<0.01	0.01 ^b
Toxaphene (ng/L)	<0.1	0.1 ^b	<0.1	0.1 ^b	<0.1	0.1 ^b	<0.1	0.1 ^b	<0.1	0.1 ^b	<0.1	0.1 ^b
2,4-D (ng/L)	<5.2-147.0	53.8	<0.5-54.5	17.5	2.6-66.0	29.0	11.2-17.7	14.5	1.0-114.0	31.0	<1.0-536.0	52.9
2,4,5-Tp Silvex (ng/L)	11.5-25.0	16.2	14.0-46.2	26.7	20.8-79.9	41.9	22.4-38.2	30.3	5.2-154.0	76.8	<3.5-134.0	38.7

^a Mean is significantly different than control site groundwater at the 0.05 level.^b Average concentrations below detection limit indicated.^r Stormwater lagoon and treatment plant effluent mean concentrations significantly different at the 0.05 level.^c TNTC - At least one sample to numerous to count.

Infiltration lagoon water	- 324501 through 324505
Stormwater lagoon water	- 324401 through 324404
Milton municipal supply	- 316002 and 316003
Control groundwater	- 312101 through 312104 and 310602 through 310604
Test groundwater	- 320101 through 320104, 320201 through 320204 320801 through 320804, 320901 through 320904 321001 through 321004, 321101 through 321104 321201 through 321204, 320301 through 320304 320401 through 320404, 320501 through 320504 321301 through 321304, 321401 through 321404 321501 through 321504, 321601 321801 through 321804, 321901 through 321904

Statistical Comparison

A statistical comparison of mean concentrations of various parameters in the treatment plant effluent applied to the infiltration lagoons and for the control site groundwater wells (31060 and 31210) was made at the 0.05 level of significance using the method of pooled variances. For purposes of the evaluation, analytical data determined below the limit of detection was arbitrarily input at one-half the detection limit value to obtain a mean value. For this reason, mean values for some parameters were reported lower than the limit of detection values indicated in Table 8.

The analysis showed significant differences in the mean concentrations existed for 13 of the 48 parameters analyzed (Table 8). In each case, except for dissolved oxygen, the parameter mean concentration was greater in the treatment plant effluent applied to the test site than for the control site groundwater. Many metal concentrations were consistently below detection limits in the effluent and control site groundwater. For both total coliform and fecal coliform, at least one sample value from the treatment plant effluent analyzed too numerous to count (TNTC) and prevented the statistical comparison of the means for these two parameters with those of the control site groundwater.

In a statistical comparison of the infiltration lagoon water with control site groundwater, significant differences at the 0.05 level were also found to exist for 13 parameters (Table 8). For each of these parameters, the concentration was greater for the infiltration lagoon water than for the control site groundwater. As in the previous comparison, mean concentrations for most metals were below detection limits. For bacteria, at least one sample of the infiltration lagoon water yielded total coliform and fecal coliform counts too numerous to count. There was no significant difference at the 0.05 level for the remaining parameters.

A statistical comparison between stormwater lagoon water and treatment plant effluent showed 15 parameters were significantly greater in the

treatment plant effluent. Only the dissolved oxygen mean concentration was found to be significantly greater in the stormwater lagoon water.

Effluent Constituents

Effluent five-day biochemical oxygen demands (BOD_5) ranged from 12 to 52 mg/L, with an average of 28 mg/L. The range for suspended solids (SS) concentrations was 11 to 45 mg/L with an average of 29 mg/L. The highest BOD_5 and SS concentrations were observed in the June, 1977, sampling, which was somewhat unusual inasmuch as most treatment plants improve treatment performance during warm seasons. However, as this was a sampling composited over a single day, it is not possible to conclude that there was any overall seasonal trend.

The chemical oxygen demand (COD) concentration was in a normal range of 48 to 112 mg/L with an average of 84 mg/L. This range and average correlated well with the BOD_5 concentrations, which were generally one-third the COD concentrations for secondary effluent. The October, 1976, and June, 1977, COD concentrations were both at the high end of the range at 112 mg/L. The June result correlated well with the corresponding high June BOD_5 result, but the October, 1976, result was anomalous since the corresponding BOD_5 was measured at 12 mg/L.

The ammonium nitrogen concentration was in a range of 10.0 to 25.6 mg/L with an average of 19.0 mg/L. Nitrate nitrogen concentrations ranged from 1.0 to 12.6 mg/L with an average of 5.3 mg/L. Total organic nitrogen concentrations ranged from <0.1 to 12.0 mg/L with an average in the range of 6.5 mg/L. When the ammonium concentration in the October, 1976, sample was low at 10 mg/L, the nitrate nitrogen was correspondingly high at 12.6 mg/L. Total nitrogen was the sum of total organic nitrogen or soluble organic nitrogen if the total value was unavailable, plus ammonia and nitrate nitrogen. Total nitrogen concentration for Milton effluent ranged from 11.1 mg/L to 50.2 mg/L with the higher total nitrogen concentrations correlating with the samples with higher total organic nitrogen and higher observed SS concentrations. These nitrogen characteristics, individually and collectively, were typical of a secondary effluent produced by an activated sludge treatment process.

Concentrations of total phosphorus were in the range of 7.10 to 9.50 mg/L with an average of 8.20 mg/L. Soluble phosphorus and soluble orthophosphate concentrations were predictably less with ranges of 6.40 to 8.50 and 6.00 to 8.00 mg/L and averages of 7.80 and 7.00 mg/L, respectively. There were no significant variations between samplings, and the results were typical for secondary effluents.

Sodium, boron, potassium, sulfate, chloride, and dissolved solids showed a marked increase in concentration in the treatment plant effluent as compared with the municipal water supply. For example, the Milton municipal supply had a measured chloride concentration in the range of 3 to 6 mg/L and an average of 5 mg/L, while the Milton effluent had a chloride concentration range of 164 to 235 mg/L and an average of 200 mg/L. This was normal for a municipal secondary effluent, as was the increase in dissolved solids from

an average 338 mg/L in the municipal supply to 728 mg/L in the treatment plant effluent.

Among the indicator pesticides and herbicides, lindane and 2,4-D were the only parameters showing higher concentrations in the effluent as contrasted with the municipal supply. Lindane and 2,4-D concentrations in the effluent ranged from 14.7 to 108.0 and <5.2 to 147.0 ng/L, with an average of 41.0 and 53.8 ng/L, respectively. Municipal water supply concentrations were in the range of <0.2 to 0.5 and 11.2 to 17.7 ng/L with averages of <0.4 and 14.5 ng/L, respectively. The stormwater lagoon concentration of lindane ranged from 1.0 to 124.0 ng/L with an average of 35.6 ng/L. All of the reported values for the municipal supply, treatment plant effluent, and stormwater lagoon are substantially less than the recommended maximum contaminant levels for lindane and 2,4-D of 4,000 and 100,000 ng/L, respectively, in the National Interim Primary Drinking Water Regulations.

Overall observations that could be made concerning the Milton treatment plant effluent were: (1) virtually all parameters were typical of secondary effluent from an activated sludge treatment plant with increased concentrations of BOD₅, SS, COD, nitrogen, phosphorus, sodium, boron, potassium, sulfate, chloride, and dissolved solids when compared with the Milton municipal supply water; and (2) lindane and 2,4-D were identified at above-background levels and with maximum observed concentrations of 108 and 147 ng/L, respectively.

Infiltration Lagoon Constituents

As a method of effluent treatment and disposal, the City of Milton has been using continuously flooded infiltration lagoons since 1957. The only addition other than effluent to the lagoons was surface runoff in close proximity to the lagoon. Since 1962 there have been three lagoons in series with a total area in the range of 2,840 m² (30,500 ft²) comprising the infiltration system. With an effluent feed rate in the range of 870,000 to 1,140,000 L/d (230,000 to 300,000 gpd), this corresponded to a lagoon application as well as an infiltration rate of 0.3 to 0.67 m (1 to 2.2 ft) per day, depending upon whether all three lagoons were actively infiltrating. Only the third lagoon, consisting of approximately 1,860 m² (20,000 ft²), was reportedly serviced and maintained in order to guarantee continued infiltration capability. This would correspond to an infiltration rate of 110 to 244 m (365 to 800 ft) per year. The other two lagoons served only as settling basins for the removal of suspended solids. For the reported lagoon depth of 2.4 to 4.6 m (8 to 15 ft), the three cell system provided about 6 to 11 days of temporary surface storage.

The BOD₅ concentration of the infiltration lagoon water varied from 5 to 39 mg/L with an average of 23 mg/L, which was comparable with the average effluent concentration of 28 mg/L. The November, 1976, lagoon sample had a measured BOD₅ concentration of 5 mg/L, which was likely incorrect as it was inconsistent with the observed COD concentration for the same sample. Little to no reduction of BOD₅ concentrations was observed due to the lagoon retention time of about 6 to 11 days.

Suspended solids concentrations ranged from 16 to 33 mg/L and averaged 25 mg/L as contrasted with an average applied effluent concentration of 29 mg/L. Again, SS removal was not significantly benefited due to the lagoon retention time.

Chemical oxygen demand concentrations ranged from 49 to 82 mg/L and averaged 63 mg/L. When compared with the average COD concentration of the effluent of 84 mg/L, there was a significant reduction. There could be a correlation between this 21 mg/L loss of organic constituents and the nitrogen loss that was also observed during retention in the lagoons.

Ammonia, organic nitrogen, and nitrate nitrogen in the lagoons ranged from 13.3 to 30.2, from <0.1 to 5.3, and from 1.0 to 10.0 mg/L with averages of 19.2, 3.4, and 3.7 mg/L, respectively. Total nitrogen averaged 26.3 mg/L as contrasted with 30.8 mg/L in the applied effluent. This 4.5 mg/L nitrogen loss was probably due to sedimentation of nitrogen-bearing solids, contributions to algae and aquatic weed growth, and denitrification. Assuming a denitrification mechanism, a quantity of COD constituent in the range of 19 mg/L would be consumed in the process. This could account for the 21 mg/L change in COD discussed earlier.

Total phosphorus, soluble phosphorus, and soluble orthophosphate phosphorus concentrations ranged from 1 to 7.5, 0.9 to 6.8, and 0.8 to 6.3 mg/L and averaged 5.4, 4.8, and 4.2 mg/L, respectively. Compared with average applied effluent concentrations of 8.2, 7.8, and 7.0 mg/L, respectively, there was a significant decrease in phosphorus concentrations. The contributing mechanisms for this reduction were sedimentation of phosphorus containing solids, the uptake by algae and aquatic weeds, and the contributions to microbial synthesis. Review of the seasonal effects on phosphorus as well as other algae-related parameters--such as nitrogen, suspended solids, and pH--does not indicate strong algal growth activity, possibly because of the relatively short retention time. The November, 1976, sample had measured phosphorus concentrations in the range of 0.9 mg/L. These results were unexplainably low and either truly anomalous or were incorrect.

Sodium, boron, potassium, sulfate, lindane, chloride, and dissolved solids all passed through the infiltration system relatively unchanged, as indicated in Table 8. For example, chloride and dissolved solids in the lagoon ranged in concentrations from 173 to 227 mg/L and from 568 to 805 mg/L, respectively, with averages of 188 and 721 mg/L, respectively. Corresponding applied effluent average concentrations were 200 and 728 mg/L, respectively. These parameters were relatively refractory, or resistant to change, in the lagoon environment.

The 2,4-D concentration ranged from <0.6 to 54.5 ng/L with an average of 17.5 ng/L. This compared favorably with the average concentration in the municipal supply and when compared with the average effluent concentration of 53.8 ng/L, suggests a reduction of 2,4-D concentration during the 6 to 11 days of retention in the lagoons.

The overall observations that could be made concerning the infiltration lagoon constituents are that: (1) biochemical oxygen demand and suspended

solids, although susceptible to change in a lagoon environment, were either unchanged or in a slightly reduced concentration; (2) chemical oxygen demand, nitrogen, and phosphorus concentrations were significantly reduced during the 6 to 11 day retention in the lagoon environment, and the COD and nitrogen reductions may have been connected through denitrification mechanisms; (3) sodium, boron, potassium, sulfate, lindane, and chloride concentrations resisted change in the lagoon environment; and (4) 2,4-D concentration in the infiltration lagoon was about 33% of that in the plant effluent and approached the background levels present in the Milton municipal water supply.

Stormwater Lagoon Constituents

A low-lying basin and marshy area located west of the Milton treatment plant and consisting of an estimated 7,400 m² (80,000 ft²) acts as a stormwater runoff interceptor and infiltration area. This stormwater lagoon contained a permanent pool that was sampled at the same time as the effluent and the infiltration lagoon.

The BOD₅ concentrations of the stormwater lagoon varied from 6 to 18 mg/L and averaged 12 mg/L, while the SS concentrations ranged from 5 to 28 mg/L with an average of 17 mg/L. The BOD and SS concentrations observed in the October, 1976, and June, 1977, samples were in the high ranges for both parameters. The average concentrations for these parameters, while greater than the respective concentrations in the Milton municipal water supply, were considerably less than the respective concentrations in either the effluent or the infiltration lagoon and were consistent with the concentration ranges encountered in surface runoff.

The COD concentrations varied from 28 to 97 mg/L, with an average of 53 mg/L, as compared with the average infiltration lagoon COD concentration of 63 mg/L. Thus, the COD in the stormwater lagoon was present in nearly the same concentrations as in the infiltration lagoon. The highest COD concentration was observed in the June, 1977, sample. Inasmuch as all soluble parameters, including refractory parameters, were measured at relatively high concentrations at this sampling time, it is possible that evapotranspiration effects contributed to the observed high concentrations.

The ammonium, soluble organic nitrogen, and nitrate nitrogen concentrations ranged from <0.1 to 0.8, 0.1 to 2.0, and <0.1 to 2.6 mg/L, respectively, and averaged 0.3, 0.8, and 1.3 mg/L, respectively. Total nitrogen averaged 2.4 mg/L, which contrasted with infiltration lagoon average total nitrogen of 26.3 mg/L. The measured nitrogen constituents were variable during the four samplings reflecting the variable nature of stormwater runoff reaching the retention lagoon.

Total phosphorus, soluble phosphorus, and soluble orthophosphate phosphorus concentrations ranged from 0.09 to 4.0, 0.07 to 3.9, and <0.01 to 3.3 mg/L, respectively, and averaged 2.0, 1.9, and 1.6 mg/L, respectively. The corresponding infiltration lagoon average concentrations were 5.4, 4.8, and 4.2 mg/L, respectively; the water in the stormwater retention lagoon had less than half the phosphorus content of the infiltration lagoon water. Phosphorus

concentrations in the stormwater lagoon, consisting primarily of soluble orthophosphate phosphorus, were in the high concentration ranges during the October, 1976, and June, 1977, samplings. The colder season samplings were relatively stripped of all soluble phosphorus. Though the pH reading of 9.4 taken in June, 1977, suggested that there was algal activity at the time, the interrelationship of algal activity to the observed phosphorus and nitrogen concentrations was not obvious from the data.

Sodium, boron, potassium, and chloride were present in concentration ranges between those measured in the municipal supply and the treatment plant effluent. This indicated that these parameters occurred in the stormwater runoff as a result of man's activities on the land. For example, the stormwater chloride concentrations ranged from 4 to 50 mg/L and averaged 22 mg/L, while the average municipal water supply and effluent concentrations were 5 and 200 mg/L, respectively.

Sulfate and dissolved solids concentrations ranged from 5 to 17 and 114 to 258 mg/L, with an average of 11 and 154 mg/L, respectively. Comparable average municipal water supply concentrations were 22 and 338 mg/L, respectively, and comparable effluent average concentrations were 51 and 728 mg/L, respectively. Thus, the origin of stormwater was indicated by these parameters to be precipitation with a relative absence of geochemical contributions, such as hardness, alkalinity, and sulfate. The calcium, magnesium, and total alkalinity for the stormwater averaged 13, 4, and 64 mg/L, as opposed to 72, 35, and 290 mg/L, respectively, for the municipal water supply.

Lindane, 2,4-D, and 2,4,5 TP silvex concentrations were in the ranges from 1 to 124, 2.6 to 66, and 20.8 to 79.9 ng/L, respectively, and averaged 35.6, 29.0, and 41.9 ng/L, respectively. Comparable average concentrations in the municipal supply were <0.4, 14.5, and 30.3 ng/L, respectively. The average 2,4-D and 2,4,5 TP silvex concentrations in the stormwater exceeded the respective concentrations of 17.5 and 26.7 ng/L in the infiltration lagoon, seeming to indicate that the source of pesticides and herbicides was stormwater runoff. Inasmuch as the National Interim Primary Drinking Water Regulations have recommended maximum contaminant levels for lindane, 2,4-D, and 2,4,5 TP silvex of 4,000, 100,000, and 10,000 ng/L, respectively, there did not appear to be reason for concern.

Overall observations that could be made concerning the stormwater constituents were that: (1) BOD₅, SS, and nitrogen concentrations were low compared to infiltration lagoon concentrations; (2) COD concentrations were comparable but slightly less than infiltration lagoon concentrations; (3) phosphorus concentrations were slightly less than half the concentrations observed in the infiltration lagoon; (4) sodium, boron, potassium, and chloride concentrations were markedly less than infiltration lagoon concentrations but greater than municipal supply concentrations, thereby denoting the contribution of urbanization to stormwater runoff; (5) sulfate and dissolved solids concentrations were less than infiltration lagoon and municipal supply concentrations, indicating the origin of stormwater as precipitation and the absence of geochemical contributions of constituents such as calcium, magnesium, sulfate, and alkalinity; and (6) lindane, 2,4-D, and 2,4,5 TP

silvex were present in above-background concentrations, indicating the probable source for pesticides and herbicides was stormwater runoff.

Municipal Supply Constituents

The Milton municipal water supply was derived from the bedrock and limestone aquifer underlying the Milton area. Knowledge of water supply constituents was necessary to provide background concentrations that could be compared with concentrations in the treatment plant effluent. The individual constituent ranges and average concentrations tabulated in Table 8 (page 47) have been discussed in the foregoing discussions of effluent and infiltration and stormwater lagoon waters.

Groundwater

Groundwater that was affected by infiltration flows from either the infiltration lagoons or the stormwater lagoon will be referred to as test groundwater, and upgradient groundwater removed from infiltrating flow interaction will be termed control groundwater.

Infiltrating flows from the infiltration lagoons were projected to enter the alluvium at a rate of 0.3 to 0.67 m (1 to 2.2 ft) per day. For the projected alluvium porosity of 20 percent, the resulting groundwater percolation rate was a minimum of 1.5 to 5 m (5 to 15 ft) per day. The saturated zones in the alluvium underlying the infiltrating effluent and the stormwater were from 6 to 11 m (20 to 35 ft) and 11 to 12 m (35 to 40 ft) below ground level, respectively. The minimum unsaturated zone immediately below the deepest part of the effluent infiltration lagoon was only 2.5 m (8 ft). Control groundwater saturated zones were a minimum of 15 to 18 m (50 to 60 ft) below ground level (Table 2).

The saturated zones under both the infiltration and the stormwater lagoons were somewhat mounded so that groundwater flow traveled away from the infiltration zones (Figure 6, page 15). The interface or saddle in the groundwater contours between the two groundwater mounds caused the groundwater to change direction of flow. The resultant groundwater flow from under the infiltration lagoons proceeded northwest, north, and northeast, while the resultant groundwater flow generated by the stormwater lagoon was to the west, northwest, and north. The northerly resultant flows of groundwater, generated from the groundwater saddle between the infiltration and the stormwater lagoons, were a mixture of control groundwater flow from the south and infiltration and stormwater lagoon flows.

In order to determine the magnitude of such effects, monitoring wells were installed at the groundwater test sites and an upgradient control area (Figures 2 and 5, pages 10 and 14). Groundwater samples were taken from these wells four times during the year of the project.

Using the sample data, comparisons of the mean concentrations of various parameters in the test and control groundwater were made using statistical techniques. In general, a comparison consisted of defining the regions of interest, computing sample parameter means for the regions of interest, and

testing for the existence of significant differences in the means at the 0.05 level, using the method of pooled variances.

In the previous comparison (Table 8), mean concentrations for 13 parameters of the 48 analyzed were found to be significantly greater in the treatment plant effluent at the test site than in the control groundwater. Similarly, 13 parameters were significantly greater for the infiltration lagoon water compared to the control groundwater and 15 parameters were significantly greater for the treatment plant effluent compared to the stormwater lagoon water. In the following discussion, references to these parameters are frequently made in order to trace the relative changes that occurred as the treatment plant effluent applied to the infiltration lagoons percolated to the groundwater.

The first analysis compared parameter mean concentrations for test groundwater in the immediate vicinity of the infiltration lagoons to those for the control groundwater. Specifically, the test site well numbers were 32010, 32020, 32080, 32090, 32100, 32110, and 32120. The control site wells were 31060 and 31210. The results are shown in Table 9. Mean concentrations for conductivity, total alkalinity, dissolved solids, chloride, ammonia, soluble phosphorus, soluble orthophosphate, boron, potassium, and sodium were found to be significantly greater at the 0.05 level in the test site groundwater than in the control site groundwater. These parameters were also among the 13 previously identified as being significantly greater in the treatment plant effluent, suggesting possible leaching for these parameters. Dissolved oxygen, pH, and nitrate mean concentrations were found to be significantly greater in the control groundwater than in the test site groundwater. Also, concentrations for many of the metals were below the detection limits in the test site groundwater, which was consistent with the results of the previous analysis for the treatment plant effluent. For the remaining parameters, no significant difference at the 0.05 level was found between the test and the control site groundwaters.

The next two analyses involved arbitrarily dividing the test site groundwater wells, previously identified, into shallow wells (<55 ft screened depth) and deep wells (>73 ft screened depth), then comparing each group with the control site wells. The results of the two analyses are shown in Tables 10 and 11, respectively. The shallow wells were 32010, 32020, 32080, 32090, and 32100. The deep wells were 32110 and 32120. Parameter mean concentrations for conductivity, total alkalinity, dissolved solids, chloride, ammonia, soluble phosphorus, soluble orthophosphate, boron, potassium, and sodium were found to be significantly greater for both the shallow and deep test site wells than for the control site wells. All 10 of the above parameters were also significantly greater in the treatment plant effluent, thus indicating the possible leaching of these parameters into both shallow and deep test site wells. In addition, the mean concentration for arsenic was significantly greater in the shallow test site wells than in the control site wells. Dissolved oxygen, pH, and nitrate concentrations were significantly greater in the control site wells than in either the shallow or the deep test site wells. Sulfate mean concentration was significantly greater in the control site wells than in the deep test site wells. As in the previous analyses, mean concentrations for many of the metals were below detection limits. For

TABLE 9. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE
GROUNDWATERS (WELLS IN IMMEDIATE VICINITY OF INFILTRATION LAGOONS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	7.0	1.1 ^a
pH (units)	7.7	7.5 ^a
Conductivity (μ mhos/cm)	677	1379 ^a
Total Alkalinity	282	427 ^a
Dissolved Solids	405	703 ^a
Biochemical Oxygen Demand	3.9	5.2
Chemical Oxygen Demand	18	36
Chloride	23	179 ^a
Sulfide-S	0.1 ^b	0.5
Total Coliform (#/100 mL)	17	TNTC ^c
Fecal Coliform (#/100 mL)	0	476
Dissolved Organic C	11.0	18.0
Soluble Organic N	0.5	0.7
Ammonium-N	0.2	20.3 ^a
Nitrate-N	6.7	0.8 ^a
Soluble Phosphorus	0.08	5.92 ^a
Soluble Orthophosphate	0.05	5.78 ^a
Sulfate	43	32
Aluminum	1.0	1.0 ^b
Arsenic (μ g/L)	5	33
Boron (μ g/L)	248	628 ^a
Cadmium (μ g/L)	20 ^b	20 ^b
Calcium	84	71
Cobalt (μ g/L)	50 ^b	50 ^b
Chromium (μ g/L)	50 ^b	50 ^b
Copper (μ g/L)	100 ^b	100 ^b
Iron	0.5 ^b	2.0
Lead (μ g/L)	200 ^b	200 ^b
Magnesium	37	40
Manganese	0.10 ^b	0.29
Mercury (μ g/L)	1.0 ^b	1.0 ^b
Nickel (μ g/L)	100 ^b	100 ^b
Potassium	2.1	13.5 ^a
Sodium	9	135 ^a
Zinc (μ g/L)	628	254
Selenium (μ g/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4	157.6
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	92.4
2,4,5 TP Silvex (ng/L)	76.8	41.2

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

^c TNTC - At least one sample too numerous to count.

TABLE 10. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE
GROUNDWATERS (TEST SITE SHALLOW WELLS <55 FEET DEEP)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	7.0	1.3 ^a
pH (units)	7.7	7.5 ^a
Conductivity (μmhos/cm)	677	1414 ^a
Total Alkalinity	282	429 ^a
Dissolved Solids	405	724 ^a
Biochemical Oxygen Demand	3.9	5.8
Chemical Oxygen Demand	18	40
Chloride	23	183 ^a
Sulfide-S	0.1 ^b	0.6 ^c
Total Coliform (#/100 mL)	17	TNTC ^c
Fecal Coliform (#/100 mL)	0	576
Dissolved Organic C	11.0	20.9
Soluble Organic N	0.5	0.9
Ammonium-N	0.2	19.6 ^a
Nitrate-N	6.7	0.9 ^a
Soluble Phosphorus	0.08	7.59 ^a
Soluble Orthophosphate	0.05	7.5 ^a
Sulfate	43	34 ^a
Aluminum	1.0 ^b	1.0 ^b
Arsenic (μg/L)	5	15 ^a
Boron (μg/L)	248	663 ^a
Cadmium (μg/L)	20 ^b	20
Calcium	84	69
Cobalt (μg/L)	50 ^b	50 ^b
Chromium (μg/L)	50 ^b	50 ^b
Copper (μg/L)	100 ^b	100 ^b
Iron	0.5 ^b	1.9
Lead (μg/L)	200 ^b	200 ^b
Magnesium	37	38
Manganese	0.10 ^b	0.36
Mercury (μg/L)	1.0 ^b	2.0 ^b
Nickel (μg/L)	100 ^b	100 ^b
Potassium	2.1	13.5 ^a
Sodium	9	139 ^a
Zinc (μg/L)	628	214
Selenium (μg/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4	205
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	105.5
2,4,5 TP Silvex (ng/L)	76.8	41.5

^aTest and control sites are significantly different at the 0.05 level.

^bAverage concentrations below detection limit indicated.

^cTNTC - At least one sample too numerous count.

TABLE 11. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE
GROUNDWATERS (TEST SITE DEEP WELLS >73 FEET DEEP)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	7.0	0.5 ^a
pH (units)	7.7	7.6 ^a
Conductivity (µmhos/cm)	677	1297 ^a
Total Alkalinity	282	422 ^a
Dissolved Solids	405	656 ^a
Biochemical Oxygen Demand	3.9	3.6
Chemical Oxygen Demand	18	26
Chloride	23	167 ^a
Sulfide-S	0.1 ^b	0.1 ^b
Total Coliform (#/100 mL)	17	634
Fecal Coliform (#/100 mL)	0	225
Dissolved Organic C	11.0	10.6 ^b
Soluble Organic N	0.5	0.1 ^b
Ammonium-N	0.2	22.0 ^a
Nitrate-N	6.7	0.8 ^a
Soluble Phosphorus	0.08	1.73 ^a
Soluble Orthophosphate	0.05	1.68 ^a
Sulfate	43	27 ^a
Aluminum	1.0 ^b	1.0 ^b
Arsenic (µg/L)	5	76
Boron (µg/L)	248	550 ^a
Cadmium (µg/L)	20 ^b	20 ^b
Calcium	84	76 ^b
Cobalt (µg/L)	50 ^b	50 ^b
Chromium (µg/L)	50 ^b	50 ^b
Copper (µg/L)	100 ^b	100 ^b
Iron	0.5 ^b	2.1
Lead (µg/L)	200 ^b	200 ^b
Magnesium	37	43
Manganese	0.10 ^b	0.11
Mercury (µg/L)	1.0 ^b	1.0 ^b
Nickel (µg/L)	100 ^b	100 ^b
Potassium	2.1	13.4 ^a
Sodium	9	125 ^a
Zinc (µg/L)	628	349
Selenium (µg/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4	56.3 ^b
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	61.3
2,4,5 TP Silvex (ng/L)	76.8	40.5

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

the remaining parameters, no significant difference at the 0.05 level was found.

In the next analysis parameter mean concentrations for downgradient test site wells were compared with those for the control site wells. These shallow wells, 32030 and 32040, were located downgradient from the previously mentioned test site wells. Table 12 indicates that mean concentrations for conductivity, total alkalinity, dissolved solids, chloride, ammonia, soluble phosphorus, soluble orthophosphate, arsenic, boron, potassium, and sodium were significantly greater for the test site downgradient wells than for the control site wells. With the exception of arsenic, all of the above parameters were also found to have significantly greater mean concentrations in the treatment plant effluent, indicating the possible spread of a pollution plume at least to the vicinity of these wells. Dissolved oxygen, pH, and nitrate means were significantly greater in the control site groundwater than in the downgradient test site groundwater. As with the previous analysis, most metal concentrations were below detection limits in the downgradient test site groundwater. No significant difference was found for the remaining parameters.

The next analysis compared a group of wells immediately beneath the stormwater lagoon with the test site wells. The stormwater lagoon groundwater wells were 32130, 32140, 32150, and 32160 and varied in depth from 37 to 95 feet; the test site wells were the same used for Table 8. Results of the analysis are shown in Table 13. Parameter mean concentrations for conductivity, total alkalinity, dissolved solids, chloride, ammonia, soluble phosphorus, soluble orthophosphate, boron, potassium, and sodium were significantly greater in the test site wells than in the stormwater lagoon wells. These 10 parameters were also significantly greater in the treatment plant effluent than in the control groundwater, which suggested possible dilution from the stormwater if there was comingling during downgradient movement.

To better define the dilution effect mentioned above, two comparisons were made between the stormwater lagoon wells and the control site wells. The first such analysis compared the shallower stormwater wells 32130 and 32160 (37 - 44 ft screened depth) with the control site wells (Table 14). This analysis determined that parameter mean concentrations for conductivity, dissolved solids, chloride, ammonia, soluble phosphorus, soluble orthophosphate, potassium, and sodium were significantly greater in the shallow stormwater wells than in the control site wells. The second analysis compared the deeper stormwater wells 32140 and 32150 (68 - 95 ft screened depth) with the control groundwater. As shown in Table 15, mean concentrations for conductivity, total alkalinity, dissolved solids, chloride, ammonia, boron, potassium, and sodium were significantly greater at the 0.05 level in the deeper stormwater wells than in the control groundwater wells. All the above parameters were previously found to occur at significantly greater concentrations in the treatment plant effluent than in the control site groundwater.

These comparisons show that the groundwater beneath the stormwater lagoon contained the same parameters found in the effluent at significantly

TABLE 12. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE
GROUNDWATERS (TEST SITE DOWNGRAIDENT SHALLOW WELLS <38 FEET DEEP)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	7.0	1.8 ^a
pH (units)	7.7	7.5 ^a
Conductivity (μmhos/cm)	677	1167 ^a
Total Alkalinity	282	391 ^a
Dissolved Solids	405	640 ^a
Biochemical Oxygen Demand	3.9	1.8
Chemical Oxygen Demand	18	29
Chloride	23	116 ^a
Sulfide-S	0.1 ^b	0.1 ^b
Total Coliform (#/100 mL)	17	TNTC ^c
Fecal Coliform (#/100 mL)	0	200
Dissolved Organic C	11.0	16.9
Soluble Organic N	0.5	1.9
Ammonium-N	0.2	6.9 ^a
Nitrate-N	6.7	1.8 ^a
Soluble Phosphorus	0.08	2.90 ^a
Soluble Orthophosphate	0.05	2.76 ^a
Sulfate	43 ^a	48
Aluminum	1.0 ^b	1.0 ^b
Arsenic (μg/L)	5	24 ^a
Boron (μg/L)	248	550 ^a
Cadmium (μg/L)	20 ^b	20 ^b
Calcium	84	68
Cobalt (μg/L)	50 ^b	50 ^b
Chromium (μg/L)	50 ^b	50 ^b
Copper (μg/L)	100 ^b	100 ^b
Iron	0.5 ^b	0.5 ^b
Lead (μg/L)	200 ^b	200 ^b
Magnesium	37	36
Manganese	0.10 ^b	0.99
Mercury (μg/L)	1.0 ^b	2.0 ^b
Nickel (μg/L)	100 ^b	100 ^b
Potassium	2.1	9.0 ^a
Sodium	9	113 ^a
Zinc (μg/L)	628	238
Selenium (μg/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4	3.9
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	23.6
2,4,5 TP Silvex (ng/L)	76.8	38.6

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

^c TNTC - At least one sample too numerous to count.

TABLE 13. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND STORMWATER LAGOON SITE GROUNDWATERS (WELLS IMMEDIATELY BENEATH STORMWATER LAGOON)

Parameter	Means (mg/L unless noted)	
	Stormwater Lagoon Wells	Test Site
Dissolved Oxygen	0.6	1.1
pH (units)	7.5	7.5
Conductivity (μ mhos/cm)	1119	1379 ^a
Total Alkalinity	385	427 ^a
Dissolved Solids	582	703 ^a
Biochemical Oxygen Demand	4.6	5.1
Chemical Oxygen Demand	35	36
Chloride	111	179 ^a
Sulfide-S	0.1 ^b	0.5
Total Coliform (#/100 mL)	TNTC ^c	TNTC
Fecal Coliform (#/100 mL)	0	476
Dissolved Organic C	13.2	18.0
Soluble Organic N	1.2	0.7
Ammonium-N	8.3	20.3 ^a
Nitrate-N	1.8	0.8 ^a
Soluble Phosphorus	1.41	5.92 ^a
Soluble Orthophosphate	1.26	5.78 ^a
Sulfate	25	32
Aluminum	1.0	1.0 ^b
Arsenic (μ g/L)	8	33
Boron (μ g/L)	459 ^b	628 ^a
Cadmium (μ g/L)	20 ^b	20 ^b
Calcium	68 ^b	71 ^b
Cobalt (μ g/L)	50 ^b	50 ^b
Chromium (μ g/L)	50 ^b	50 ^b
Copper (μ g/L)	100 ^b	100 ^b
Iron	1 ^{b8}	2 ^{b0}
Lead (μ g/L)	200 ^{b8}	200 ^{b0}
Magnesium	35	40
Manganese	0.84 ^b	0.29 ^a
Mercury (μ g/L)	1 ^{b0}	1 ^{b0}
Nickel (μ g/L)	100 ^b	100 ^b
Potassium	11.2	13.5 ^{a5}
Sodium	92	135 ^{a5}
Zinc (μ g/L)	179	254
Selenium (μ g/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	101.3	157.6 ^b
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	47.4	92.4
2,4,5 TP Silvex (ng/L)	29.2	41.2

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

^c TNTC - At least one sample too numerous to count.

TABLE 14. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS (STORMWATER LAGOON SHALLOW WELLS)

Parameter	Means (mg/L unless noted)	
	Control	Stormwater Lagoon Wells
Dissolved Oxygen	7.0	0.9 ^a
pH (units)	7.7	7.5 ^a
Conductivity (µmhos/cm)	677	1064 ^a
Total Alkalinity	282	337
Dissolved Solids	405	579 ^a
Biochemical Oxygen Demand	3.9	2.3
Chemical Oxygen Demand	18	44
Chloride	23	108 ^a
Sulfide-S	0.1 ^b	0.1 ^b
Total Coliform (#/100 mL)	17	TNTC ^c
Fecal Coliform (#/100 mL)	0	0
Dissolved Organic C	11.0	12.5
Soluble Organic N	0.5	0.8
Ammonium-N	0.2	3.7 ^a
Nitrate-N	6.7	3.2
Soluble Phosphorus	0.08	3.46 ^a
Soluble Orthophosphate	0.05	3.12 ^a
Sulfate	43	31 ^a
Aluminum	1.0 ^b	1.0 ^b
Arsenic (µg/L)	5	13
Boron (µg/L)	248	453
Cadmium (µg/L)	20 ^b	20 ^b
Calcium	84	69
Cobalt (µg/L)	50 ^b	50 ^b
Chromium (µg/L)	50 ^b	50 ^b
Copper (µg/L)	100 ^b	100 ^b
Iron	0.5 ^b	2.2
Lead (µg/L)	200 ^b	200 ^b
Magnesium	37	36
Manganese	0.10 ^b	1.90
Mercury (µg/L)	1.0 ^b	1.0 ^b
Nickel (µg/L)	100 ^b	100 ^b
Potassium	2.1	9.6 ^a
Sodium	9	79 ^a
Zinc (µg/L)	628	107
Selenium (µg/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4	65.8
Methoxychlor (ng/L)	0.01	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	79.2
2,4,5 TP Silvex (ng/L)	76.8	33.2

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

^c TNTC - At least one sample too numerous to count.

TABLE 15. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL
SITE GROUNDWATERS (STORMWATER LAGOON DEEP WELLS)

Parameter	Means (mg/L unless noted)	
	Control	Stormwater Lagoon Wells
Dissolved Oxygen	7.0	0.5 ^a
pH (units)	7.7	7.5 ^a
Conductivity (µmhos/cm)	677	1153 ^a
Total Alkalinity	282	418 ^a
Dissolved Solids	405	583 ^a
Biochemical Oxygen Demand	3.9	5.8
Chemical Oxygen Demand	18	29
Chloride	23	113 ^a
Sulfide-S	0.1 ^b	0.1 ^b
Total Coliform (#/100 mL)	17	TNTC ^c
Fecal Coliform (#/100 mL)	0	0
Dissolved Organic C	11.0	13.8
Soluble Organic N	0.5	1.4 ^a
Ammonium-N	0.2	12.4 ^a
Nitrate-N	6.7	0.8 ^a
Soluble Phosphorus	0.08	0.13
Soluble Orthophosphate	0.05	0.10
Sulfate	43	22
Aluminum	1.0 ^b	1.1
Arsenic (µg/L)	5	5
Boron (µg/L)	248 ^b	463 ^a
Cadmium (µg/L)	20 ^b	20 ^b
Calcium	84 ^b	67 ^b
Cobalt (µg/L)	50 ^b	50 ^b
Chromium (µg/L)	50 ^b	50 ^b
Copper (µg/L)	100 ^b	100 ^b
Iron	0.5 ^b	1.6 ^b
Lead (µg/L)	200 ^b	200 ^b
Magnesium	37	34
Manganese	0.10 ^b	0.18
Mercury (µg/L)	1.0 ^b	2.0 ^b
Nickel (µg/L)	100 ^b	100 ^b
Potassium	2.1	12.2 ^a
Sodium	9	101 ^a
Zinc (µg/L)	628	224
Selenium (µg/L)	5	5
Endrin (ng/L)	0.03 ^b	0.03 ^b
Lindane (ng/L)	7.4 ^b	123.4 ^b
Methoxychlor (ng/L)	0.01 ^b	0.01 ^b
Toxaphene (ng/L)	0.1 ^b	0.1 ^b
2,4-D (ng/L)	31	27.6
2,4,5 TP Silvex (ng/L)	76.8	26.8

^a Test and control sites are significantly different at the 0.05 level.

^b Average concentrations below detection limit indicated.

^c TNTC - At least one sample too numerous to count.

higher concentrations than found in the control groundwater yet at significantly lower concentrations than found beneath the infiltration lagoon. This shows that the infiltrated effluent is moving beneath the stormwater lagoon while being diluted from other sources. The most obvious source of dilution is the infiltrating stormwater. However, other wells downgradient from the stormwater and infiltration lagoons could also be receiving dilution from control groundwater.

The salient groundwater quality parameters that differentiated the test and control sites are discussed in more detail in the following paragraphs. In all cases, these parameters were contained in the infiltrated waters at concentrations markedly greater than those in incident precipitation. Figures 10 through 25 show values for all test site wells but only control site well 31060. The ranges and means for both control wells are shown in Table 8. The complete list and data for groundwater quality parameters are tabulated in Appendix B.

Nitrogen--

Ammonium nitrogen concentrations ranged from 0.1 to 35.4 and averaged 13.7 mg/L for test groundwater, as contrasted with a range of 0.1 to 0.6 and an average of 0.2 mg/L for control groundwater (Figure 10). No correlations were found between concentrations, depth, and season of year. A possible correlation of dilution with distance, as projected from tracer parameters such as chloride, plus the loss of nitrogen due to denitrification seems to best explain the data. For example, the average concentration of 6.9 mg/L at shallow perimeter wells 32030 and 32040 (Table 12) as compared to the average concentration of the test site shallow wells (Table 10) of 19.6 mg/L can be reasonably explained as dilution and denitrification. These wells, located 50 m (164 ft) downgradient from the infiltration lagoon, were unaffected by the groundwater flow from the stormwater lagoon and were the most representative samples of the infiltrated effluent downgradient from the lagoons. The reduction in ammonia concentration indicated considerable denitrification occurred near the top of the groundwater table. However, examination of the chloride concentrations of these wells also indicated seasonal dilution.

Soluble organic nitrogen concentrations ranged from <0.1 to 7.0 mg/L and averaged 1.0 mg/L for test groundwater, which contrasted with the range of <0.1 to 1.0 mg/L and an average of 0.5 mg/L for control groundwater (Figure 11). There were no observable trends with respect to depth or time of year. No other correlations could be established.

Nitrate nitrogen concentrations ranged from <0.1 to 10.3 mg/L and averaged 1.5 mg/L for test groundwater, as opposed to a range of 4.3 to 9.6 mg/L and an average of 6.7 mg/L for control groundwater (Figure 12). There were no observable trends with depth. Concentrations were generally in the lowest range during the April and June, 1977, samplings. The data were variable, and no other trends were observed. Nitrogen constituents in large quantities were apparently penetrating the groundwater under the infiltration lagoons. Tracer observations indicated that the infiltration lagoon was probably contributing to deeper groundwater flows under the stormwater lagoon. This possibly explained (1) the presence of higher total nitrogen concentrations

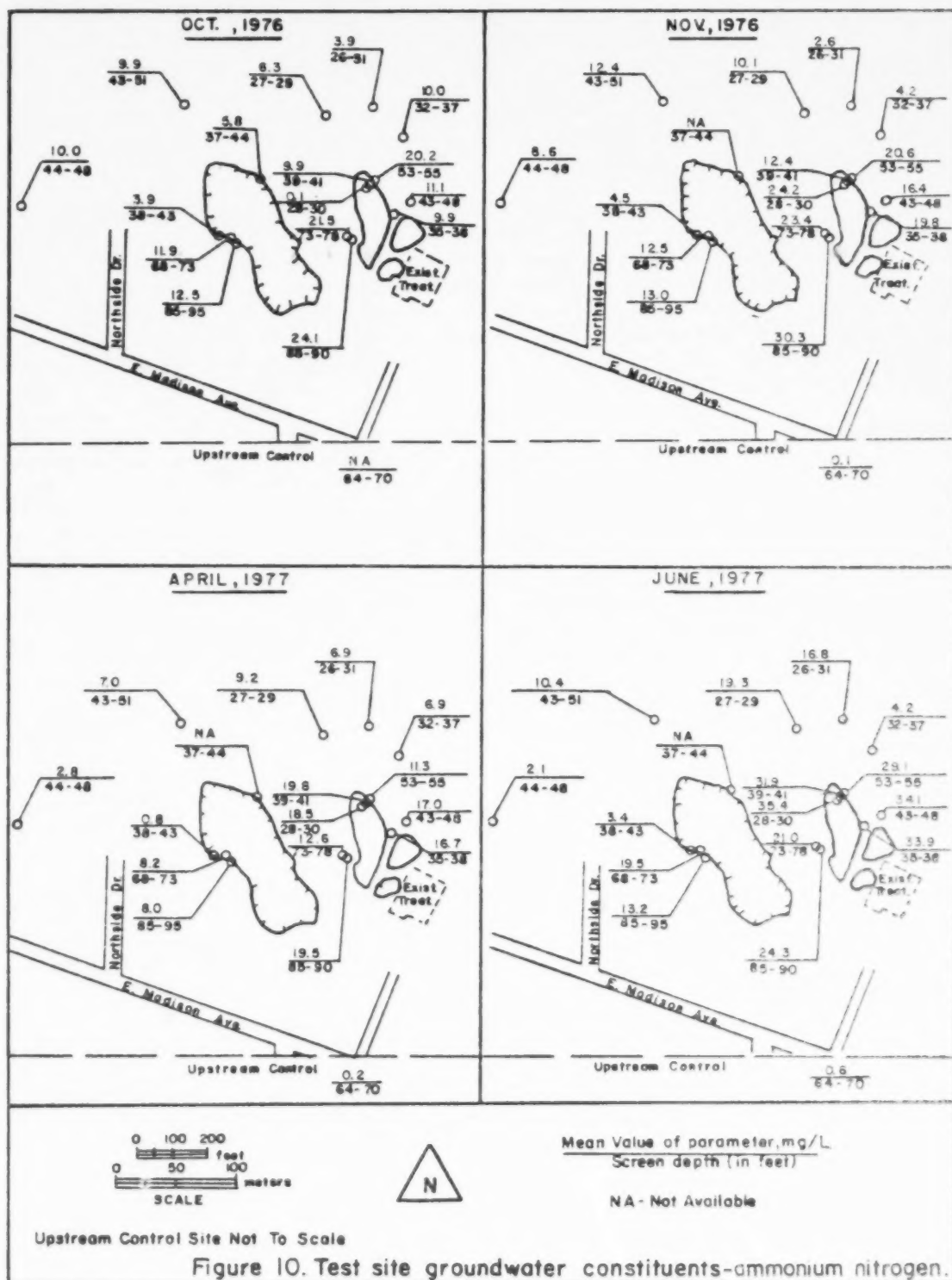
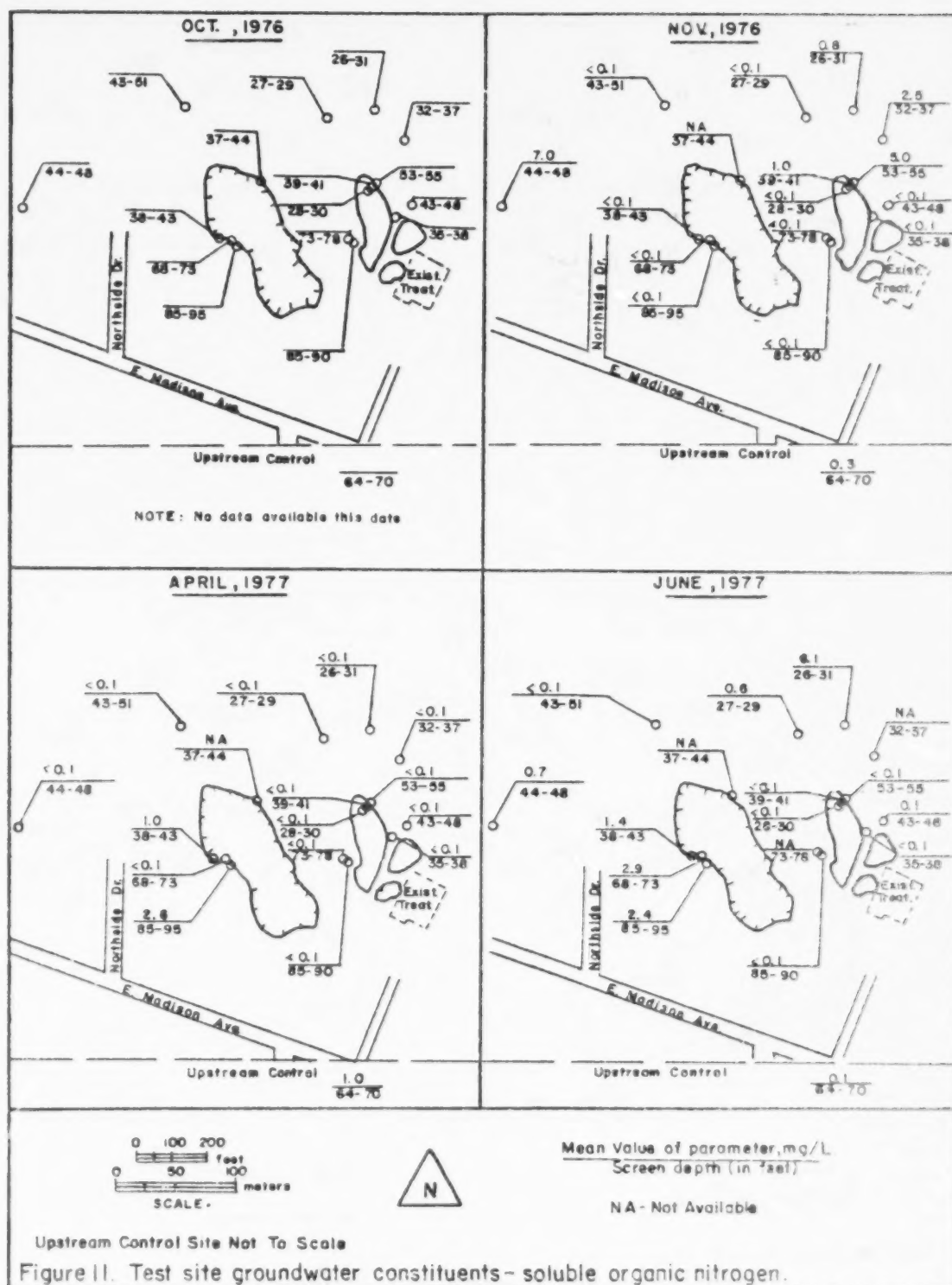
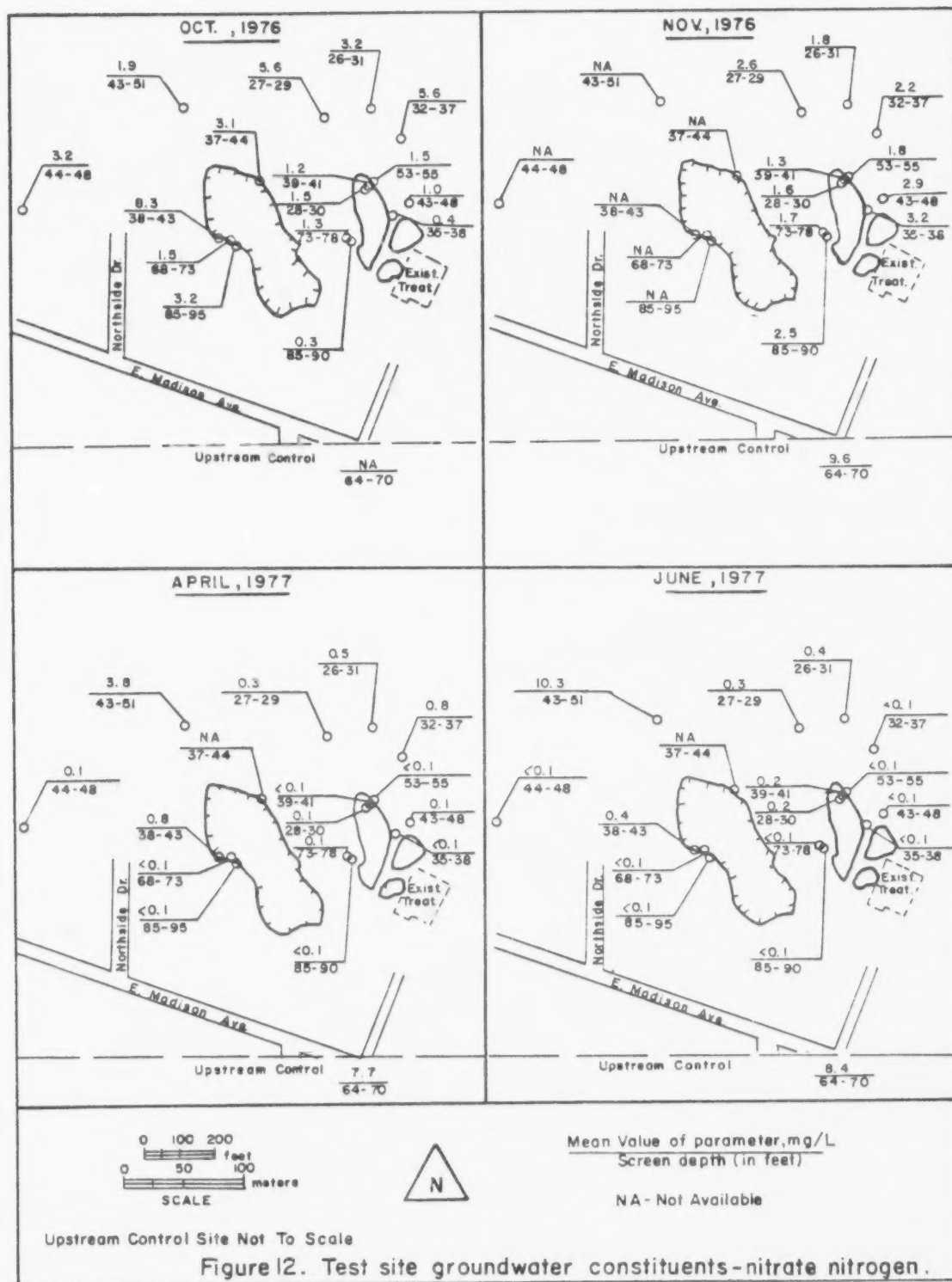


Figure 10. Test site groundwater constituents-ammonium nitrogen.





in deeper wells 32140 and 32150 as opposed to 32130 and (2) the relatively high total nitrogen concentrations in well 32190. The stormwater was not the likely source for these concentrations because of the low nitrogen concentration observed in the stormwater lagoon.

The average total nitrogen concentration applied to the infiltration lagoons was 26.3 mg/L, while the average total nitrogen concentration measured in the test groundwater was 16.5 mg/L (Table 8). The average concentration of COD applied to the infiltration lagoon was 63 mg/L and that observed in the test groundwater was 32 mg/L. The change in total nitrogen concentration observed was approximately 10 mg/L, while a 31 mg/L concentration change was observed for COD. In the denitrification process, at least four times as much COD material must be consumed in order for a given amount of nitrate nitrogen to be converted to nitrogen. Possibly the 31 mg/L loss of COD constituents could be attributed to the denitrification process.

An estimate of the total nitrogen leaving the site via the groundwater can be obtained from the average concentration of all the perimeter wells. This includes shallow wells 32030, 32040, 32050, 32130, 32180, and 32190 and deep wells 32140 and 32150. The shallow wells have average concentrations of 7.3 mg/L ammonia nitrogen, 1.2 mg/L soluble organic nitrogen, 2.5 mg/L nitrate nitrogen and 11.0 mg/L total nitrogen compared to 12.4, 1.4, 0.8 and 14.6 mg/L, respectively, for the deep wells. The wells are located from 50 to 280 m (164 to 918 ft) downgradient and have a combined total nitrogen concentration of 12.0 mg/L.

The actual renovation of the applied wastewater requires consideration of any dilution which may be occurring at the above wells from groundwater (control) inflow or stormwater infiltration. If it is assumed that chloride moves through the system unchanged, then this parameter can be used as a tracer to estimate the amount of infiltrated wastewater contributed to a particular well or group of wells. The average chloride concentration in the infiltration lagoon was 188 mg/L and the average concentration of the eight perimeter wells was 128 mg/L. Since the average chloride concentrations in the control groundwater and the stormwater were essentially the same at 23 and 22 mg/L, respectively, it was not necessary to know the individual flow components from these sources in order to calculate the dilution.

The dilution effect can then be calculated from the following equations:

$$C_A Q_A + C_B Q_B = C_C Q_C$$

and

$$Q_A + Q_B = Q_C$$

where:

C_A = Concentration in infiltrated effluent
 Q_A = Flow attributed to infiltrated effluent
 C_B = Concentration in control groundwater and stormwater
 Q_B = Flow attributed to control groundwater and stormwater
 C_C = Concentration in perimeter wells
 Q_C = Total groundwater flow at perimeter wells

Solving:

$$Q_A = \left(\frac{C_C - C_B}{C_A - C_B} \right) Q_C$$

$$Q_A = \left(\frac{128 - 23}{188 - 23} \right) Q_C = 0.636 Q_C$$

Thus, approximately 64 percent of the flow monitored at the perimeter wells was attributable to the infiltration lagoon while the remaining 36 percent was dilution from the stormwater and the control groundwater.

Since the mix of the dilution water is unknown, some additional assumptions are necessary to estimate the percent of applied total nitrogen passing the perimeter wells. If the dilution flow component contained no nitrogen, then the concentration of the infiltrated effluent at the perimeter wells would be 12.0 mg/L divided by 0.64 or 18.8 mg/L which represents 71 percent of the applied total nitrogen concentration. If the dilution is all from the control groundwater which has a total nitrogen concentration of 7.4 mg/L, then the above equations can be used to determine the total nitrogen concentration of the renovated effluent at the perimeter wells as follows:

$$C_A (0.64 Q_C) + 7.4 (0.036 Q_C) = 12.0 Q_C$$

$$C_A = \frac{9.336 Q_C}{0.64 Q_C} = 14.6 \text{ mg/L}$$

This represents 55 percent of the applied total nitrogen concentration.

The last assumption can be that all dilution is from the stormwater lagoon. The stormwater had a total nitrogen concentration of 2.4 mg/L. From the previous equations, it was calculated that 63 (55 to 71) percent or 1.5 mg/L reaches the perimeter wells. Under these conditions the total nitrogen concentration of the renovated effluent at the perimeter wells is calculated, as above, to be 17.9 mg/L or 68 percent of the applied concentration. Hence, approximately 62 (55 to 68) percent of the applied total nitrogen was passing wells located from 50 to 280 m (164 to 918 ft) down-gradient.

It should be noted, that as discussed elsewhere, most of the flow away from the infiltration lagoon is moving through a more permeable zone near the top of the water table which is monitored by the shallow wells. While a separate evaluation of the shallow perimeter wells would indicate more nitrogen removal within this zone, these calculations were not included because of the unknown deep and shallow flow components.

The nitrate and organic nitrogen concentrations migrating with the groundwater from the infiltration sites would generally not exceed any water quality standards. The ammonium nitrogen concentrations, however, exceeded safe standards for aquatic life.

Chemical Oxygen Demand--

The COD concentrations of the test and control groundwater ranged from 4 to 199 mg/L and 3 to 37 mg/L with an average of 32 mg/L and 18 mg/L, respectively (Figure 13 and Appendix B). A gradient in COD concentration with distance from the infiltration source was indicated, irrespective of dilution effects (Figure 14).

The data in Figure 13 show that, with the exception of the October, 1976, sampling, the COD concentrations in the groundwater in the perimeter wells were within the range measured in the control groundwater.

Potassium, Sodium, Boron, Chloride, Dissolved Solids--

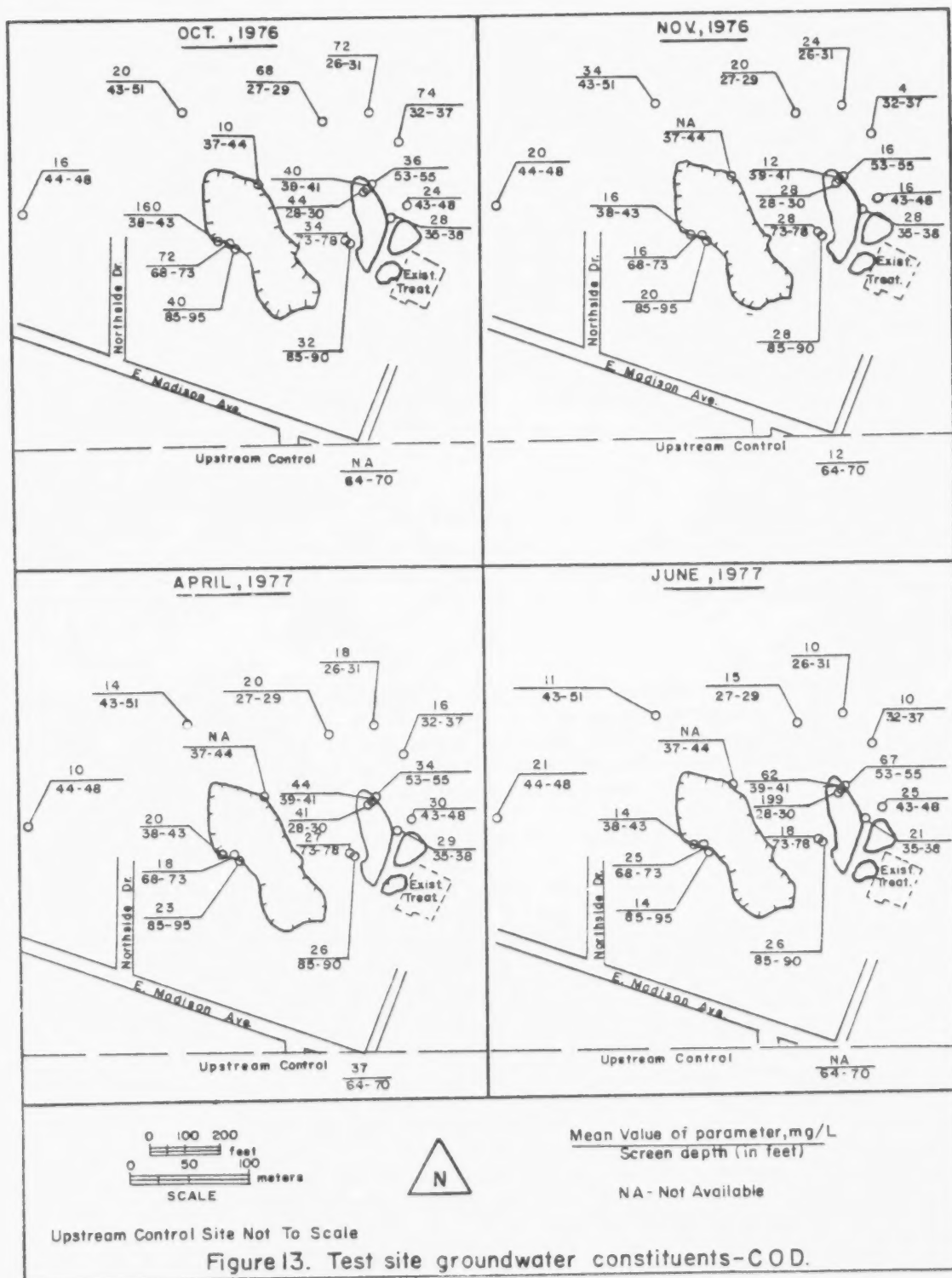
Potassium, sodium, boron, chloride, and dissolved solids remained relatively unchanged when passed through the infiltration lagoons, through the alluvium, and into the groundwater. Inasmuch as the concentrations for these parameters in the infiltration water were quite different from those of the control groundwater or stormwater, any of these parameters could be used as inert tracers to determine the percent contribution of infiltration flow to a particular groundwater flow.

Chloride and dissolved solids, for example, had test groundwater concentrations ranging from 34 to 216 mg/L and 418 to 813 mg/L, with average concentrations of 149 and 668 mg/L, respectively. Comparable control groundwater concentrations ranged from 12 to 39 mg/L and 359 to 472 mg/L, and average concentrations were 23 and 405 mg/L, respectively (Figures 15 and 16).

Phosphorus--

The soluble phosphorus and soluble orthophosphate phosphorus concentrations in the test groundwater ranged from 0.04 to 14 mg/L and 0.03 to 12 mg/L, with average concentrations of 4.0 and 3.8 mg/L, respectively. Comparable control groundwater concentrations ranged from <0.01 to 0.24 mg/L and <0.01 to 0.20 mg/L, with average concentrations of 0.08 and 0.05 mg/L, respectively (Figures 17 and 18). Phosphorus concentrations displayed a gradient with distance from the infiltration source (Figure 14).

Phosphorus concentrations in wells 32120, 32140, and 32150 were observed to be much lower than in other test site wells. It was hypothesized that, although tracer observations indicated infiltration lagoon influence was strong at these wells of low concentration, by comprising 50 to 75 percent of the flow, the total flow was reduced because of the relative depth and placement of the wells within a less permeable zone. Thus, the phosphorus removal capabilities of the intervening alluvium were preserved. By contrast, the measured results at the other monitoring wells in the test groundwater indicated that the major phosphorus removal capability of the intervening alluvium material had been expended due to years of infiltrating flows. Apparently the downgradient alluvium sediments beyond the monitored test groundwater area were providing the phosphorus removal typical of a rapid infiltration system. The soluble phosphorus was observed to be virtually all orthophosphate phosphorus and thus potentially adsorbable on the cation sites in the alluvial sediments.



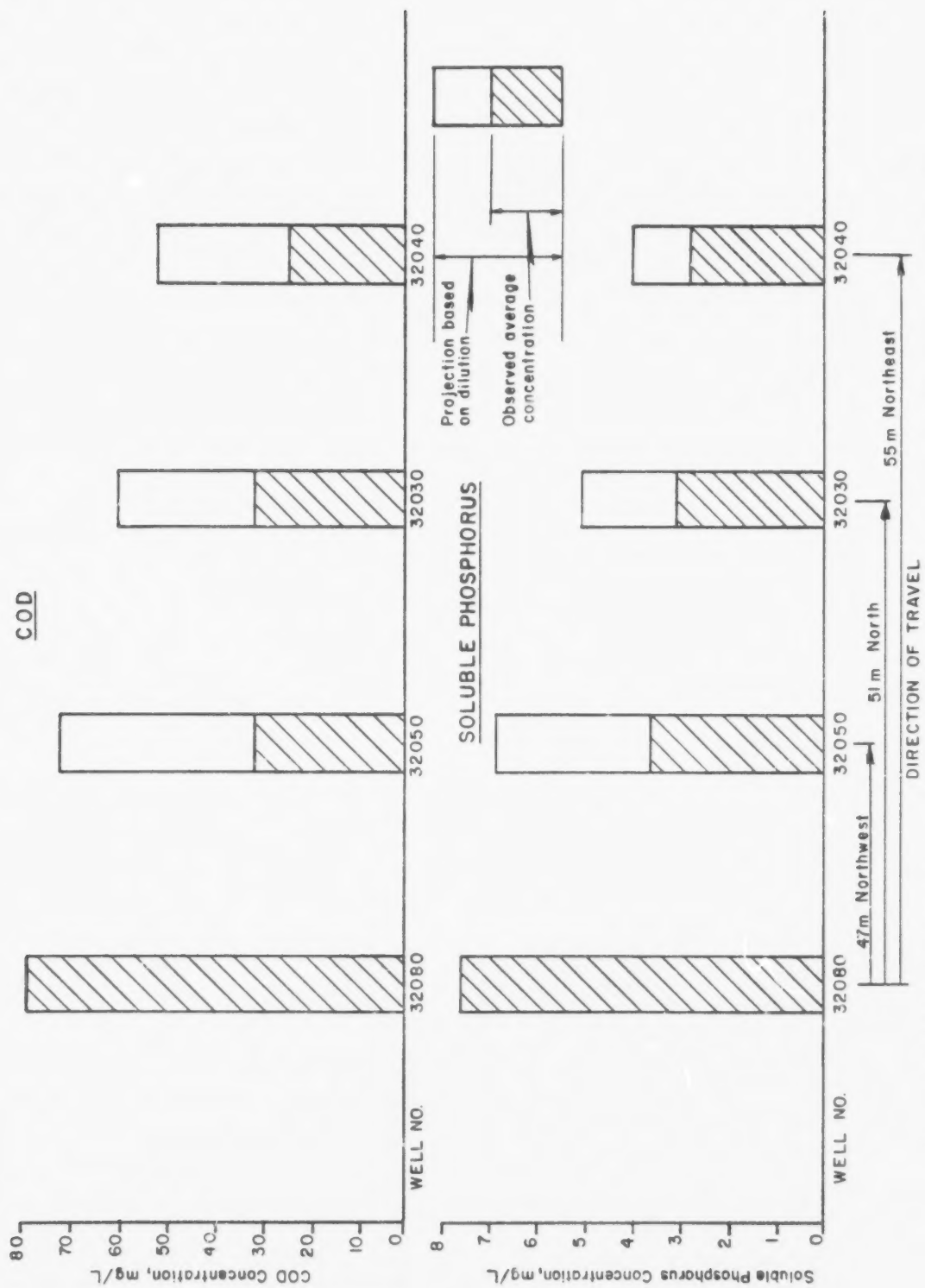


Figure 14. COD and soluble phosphorus gradient with travel from the infiltration lagoon source.

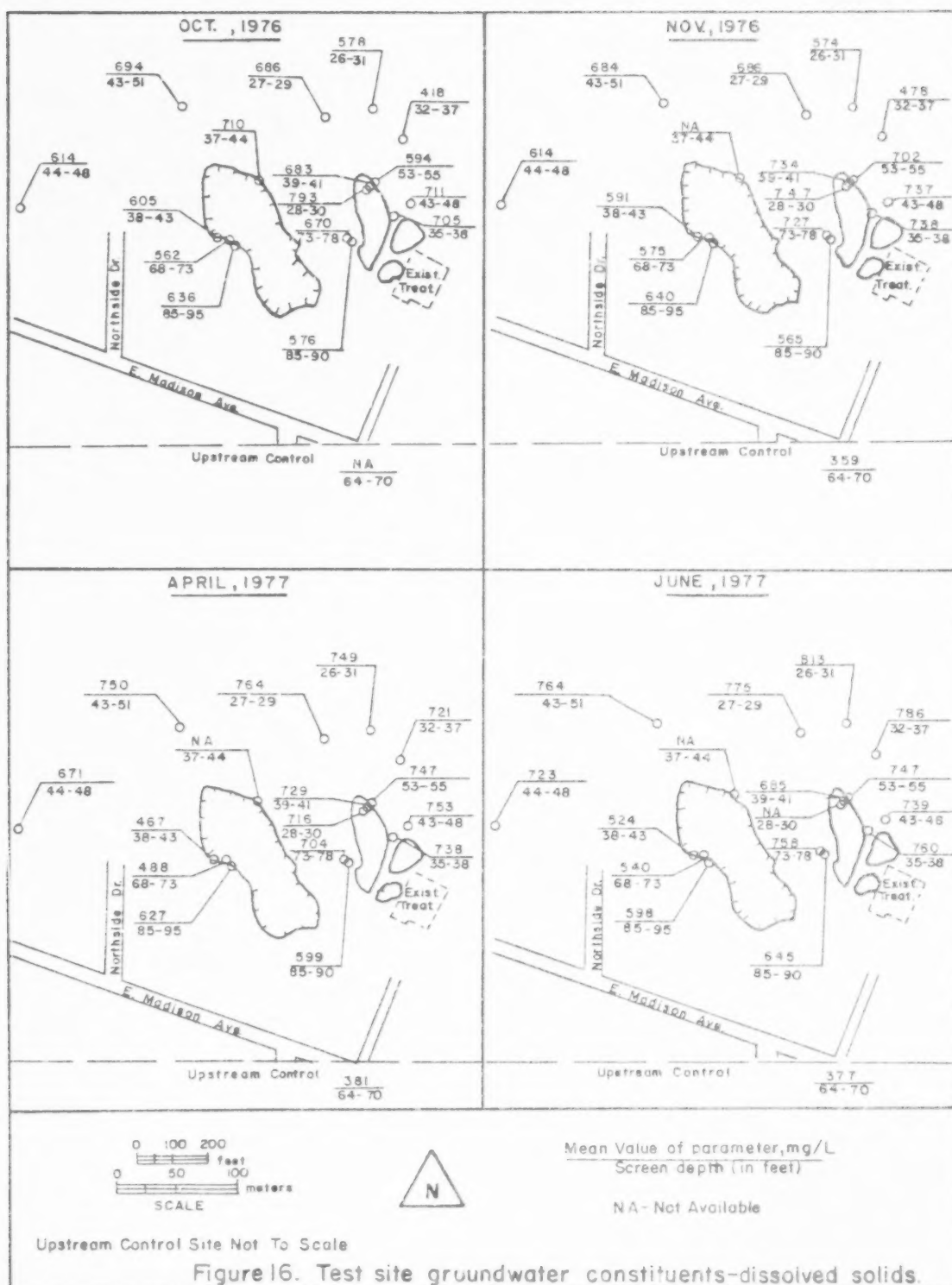
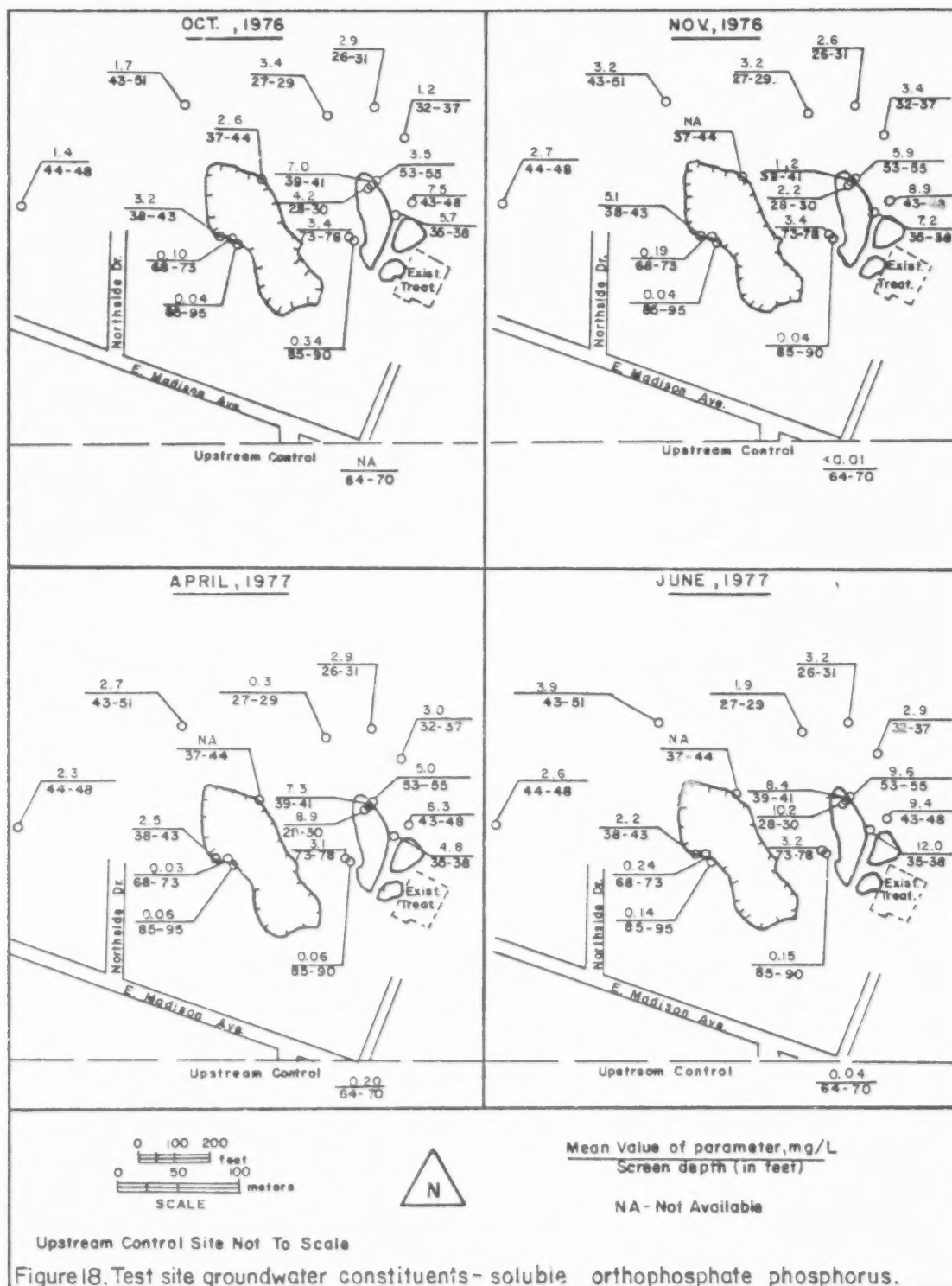


Figure 16. Test site groundwater constituents-dissolved solids.



Total phosphorus removal or the percent passing the perimeter wells can be estimated as done for total nitrogen. Total phosphorus concentration averaged 5.4 mg/L in the infiltration lagoon and 2.03 mg/L in the stormwater lagoon. The soluble phosphorus concentration averaged 0.08 mg/L in the control groundwater and 2.37 mg/L in the perimeter wells. With the same assumptions that flow at the perimeter wells consists of flow from the stormwater and infiltration lagoons only and that the percent removal is essentially the same for each source, then by a trail and error method, 57 percent of the applied phosphorus is calculated to be moving past the perimeter wells. This compares to 68 percent if all dilution comes from the control groundwater. Averaging the two is essentially an assumption that 50 percent of the dilution flow comes from each source; however, calculating the ranges shows that such an assumption is reasonably accurate regardless of the component mix from each source.

As discussed under the evaluation of nitrogen, most of the flow probably moves past and is monitored by the shallow wells. A separate evaluation of these wells for phosphorus would show a greater percentage moving beyond the perimeter wells. It is also likely that less phosphorus moves through the finer sediments (silt and clay) beneath the stormwater lagoon than through the sand and gravel beneath the infiltration lagoon. If so, this would narrow the calculated range towards the higher value. With these qualifications a higher value, say 65 percent, is probably more accurate than an average value.

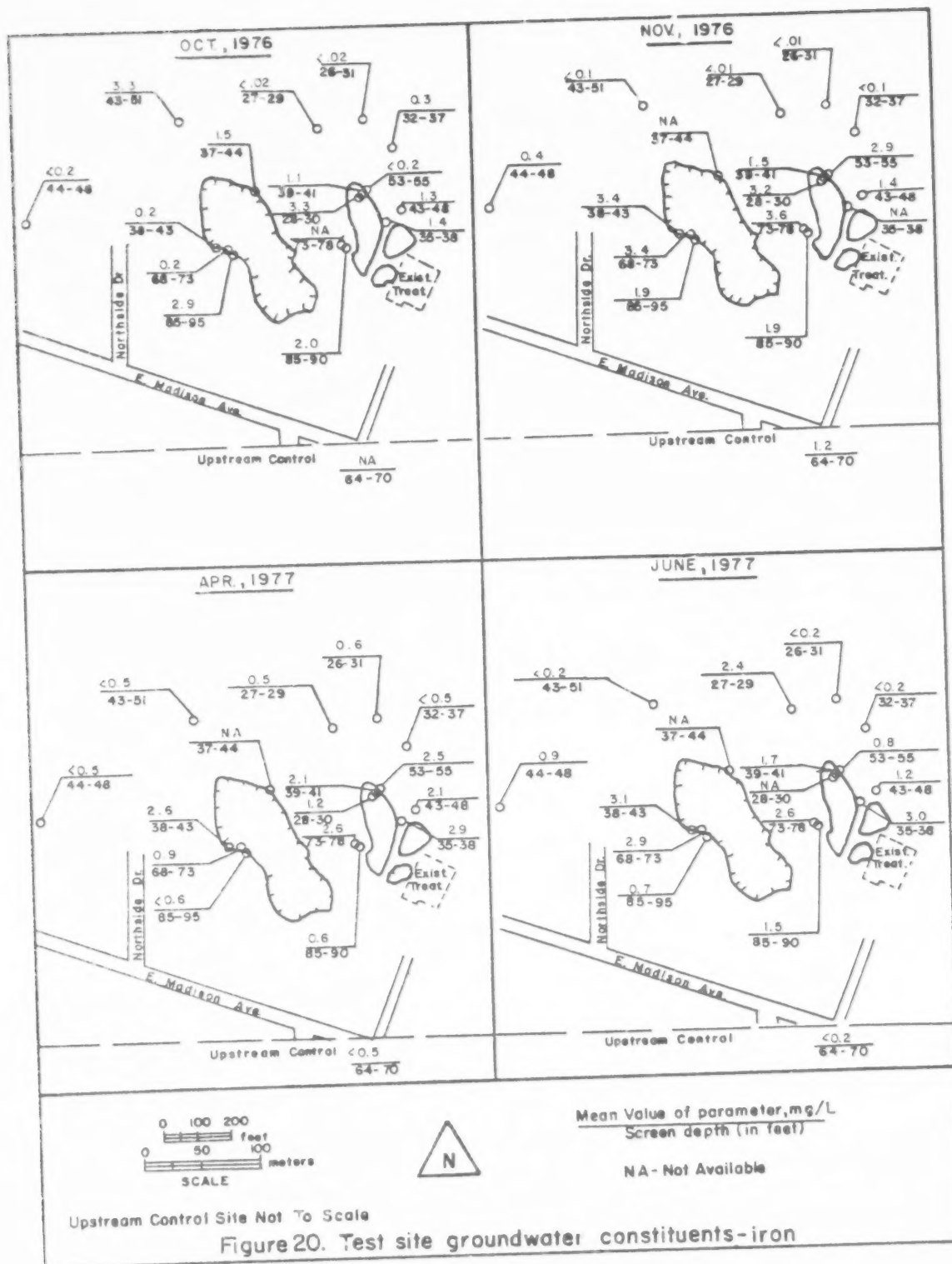
Metals--

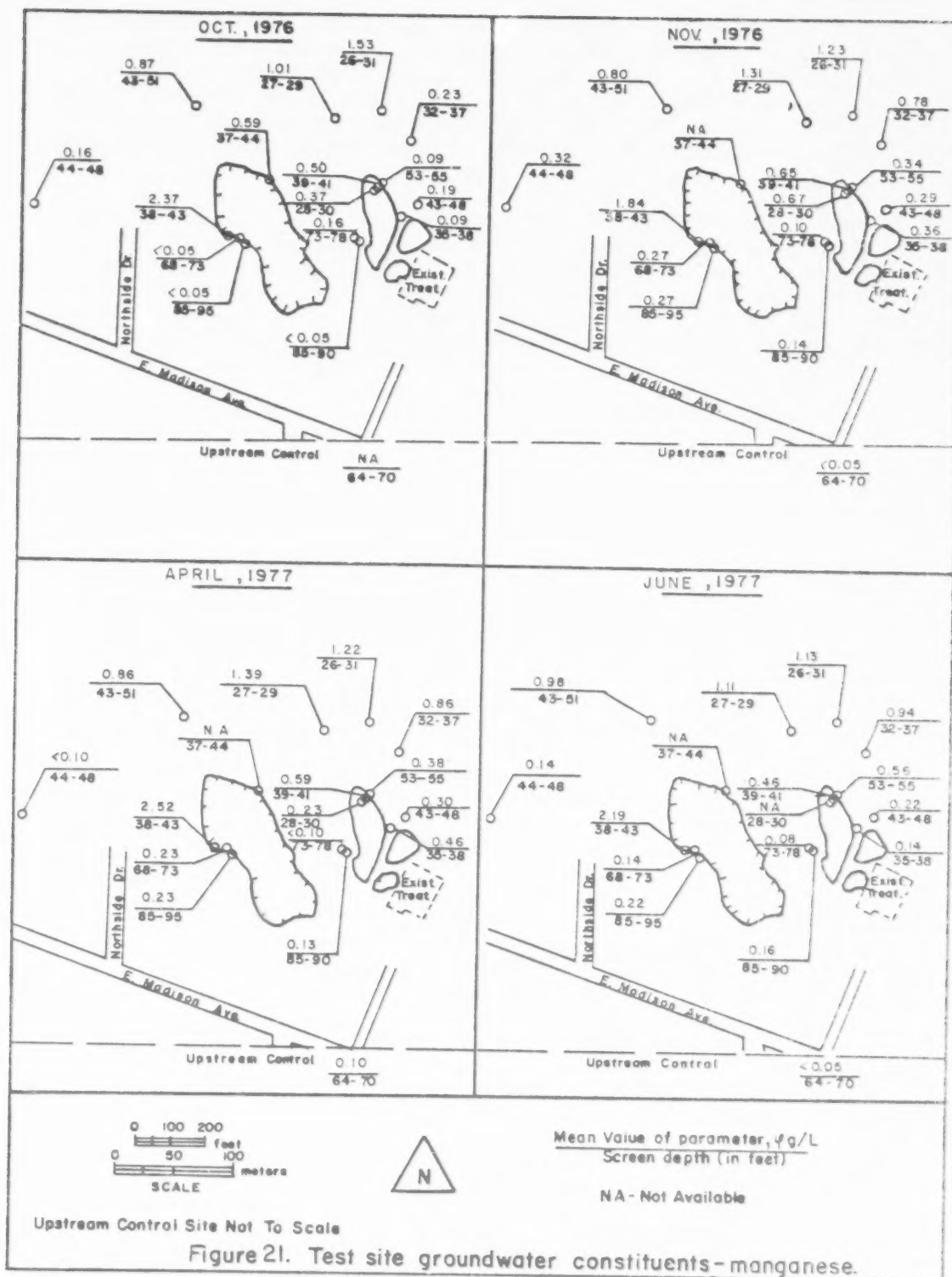
Groundwater was examined for the presence of the following metals--arsenic, cadmium, cobalt, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc. Except for arsenic, iron, and manganese, concentrations of metals were generally at or below minimum detectable levels.

Arsenic, iron, and manganese had test groundwater concentration ranges from <10 to 53 ng/L, <0.1 to 3.6 mg/L, and <0.05 to 2.5 mg/L, with averages of 24 ng/L, 1.5 mg/L, and 0.6 mg/L, respectively. Comparable control groundwater concentration ranges were <10 µg/L, <0.1 to 1.2 mg/L, and <0.05 to <0.10 mg/L, with averages of 5 µg/L, <0.5 mg/L, and <0.1 mg/L, respectively (Figures 19, 20, and 21).

A possible source of these metal constituents was the effluent from the infiltration lagoon. There were indications of minimum detectable concentrations of arsenic and iron in the effluent. However, a more likely source for the iron, manganese, and arsenic was the soil itself. The analyses of the alluvial soil samples from the test and control areas indicated that while available iron, manganese, and arsenic concentrations were higher in the test area soil, the total iron, manganese, and arsenic were depleted in contrast to the control area alluvium. Thus, it would appear that continued operation of an infiltration system could affect weathering geochemistry of the soil.

The occurrence of iron, manganese, and possibly arsenic in the test groundwater could be due to the reduction of the oxidized hydroxides of these metals in the anaerobic environment of the alluvium. The reduced





ferrous and manganous forms of these metals are soluble and could leach to the underlying groundwater. Reduced forms of arsenic are also soluble in the arsenate form and could readily adsorb on cation sites in the soil in a manner similar to orthophosphate. Since most sites in the test area alluvial soils were occupied by phosphorus compounds, some arsenate could enter the groundwater, then be removed by unoccupied sites farther down the groundwater gradient.

Of these three metals, only the iron was present in a concentration range that might cause problems. A level of iron concentration of 0.3 mg/L is considered the maximum allowable without developing nuisance problems in plumbing fixtures as a result of iron depositions and iron bacterial actions. This level was greatly exceeded. The allowable level for arsenic in drinking water supplies is 50 µg/L, which was exceeded in only one test site sample.

Pesticides and Herbicides--

The concentration ranges of lindane and 2,4-D in test groundwater were from <0.2 to 1,360 ng/L and from <1 to 536 ng/L, with average concentrations of 91.7 and 52.9 ng/L, respectively. The comparable control groundwater concentration ranges were from <0.2 to 20.7 ng/L and from 1 to 114 ng/L, with average concentrations of 7.4 and 31 ng/L, respectively (Figures 22 and 23).

Since the maximum contaminant levels for lindane and 2,4-D, as proposed by the National Interim Primary Drinking Water Regulations, are 4,000 and 100,000 ng/L, respectively, the presence of these minor concentrations slightly above background levels was not of significant concern.

Coliform Bacteria--

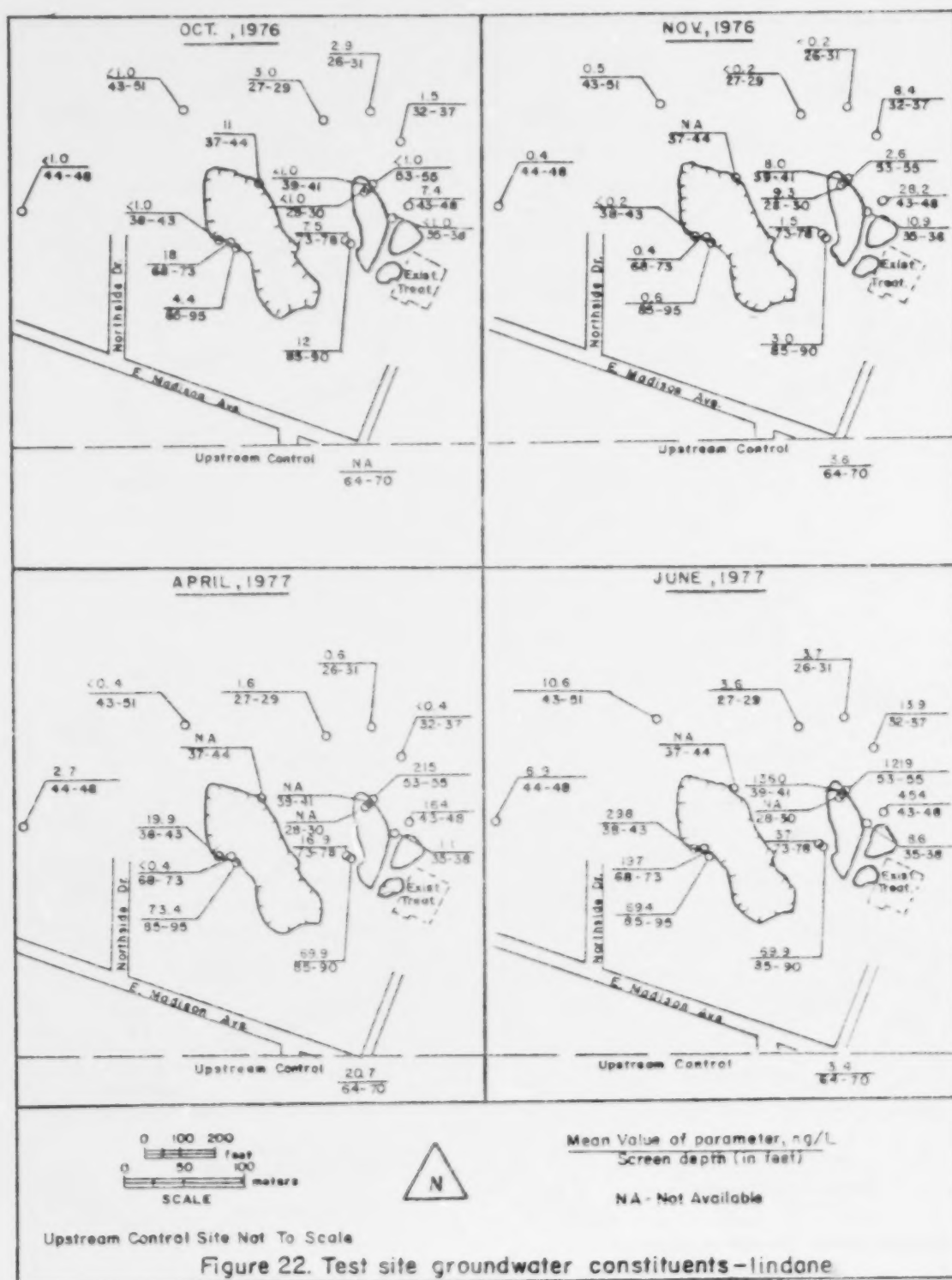
Total and fecal coliform results are shown on Figures 24 and 25. Contamination of samples was minimal due to field and laboratory precautions.

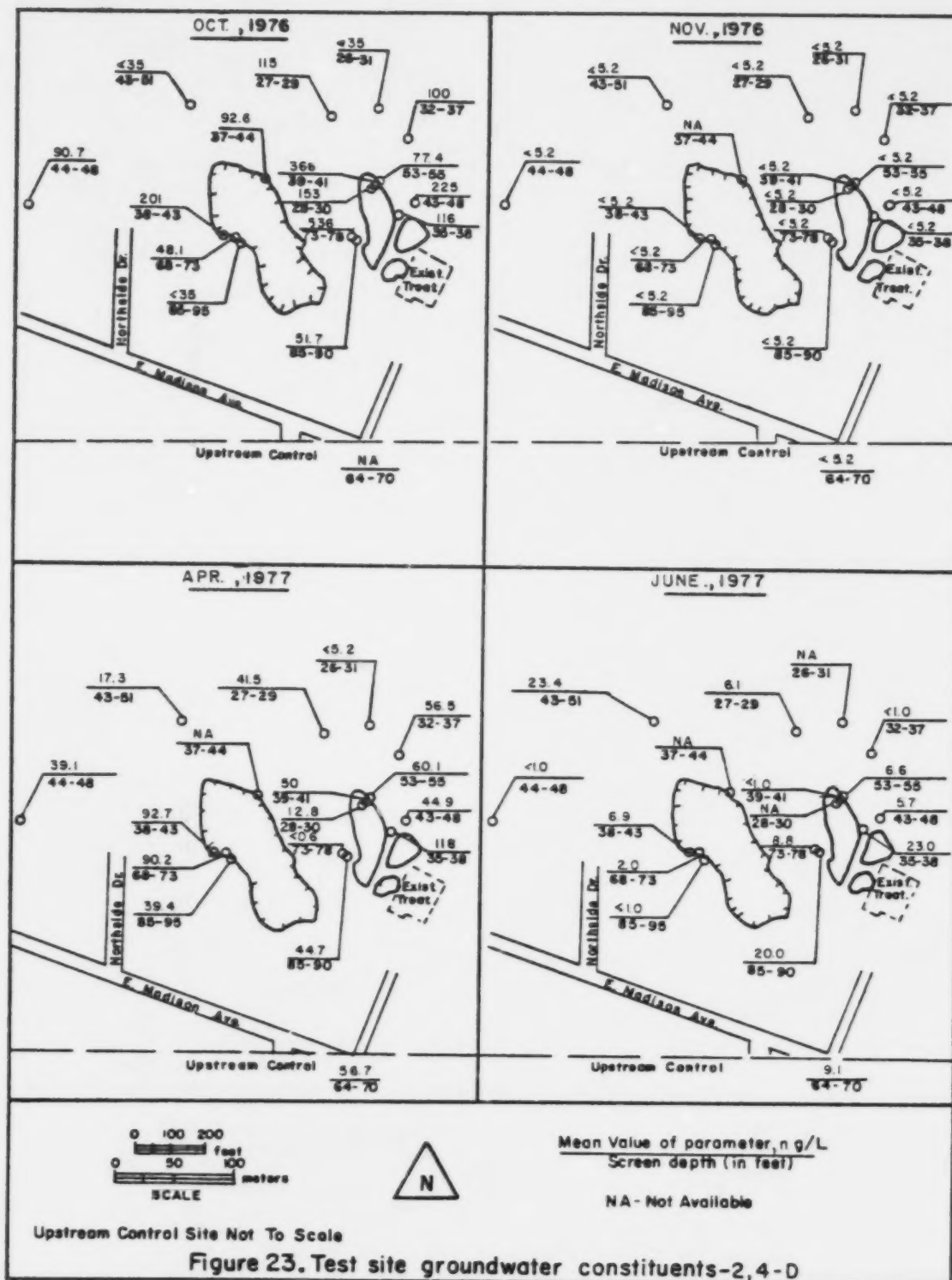
There was a pattern for both total and fecal coliform occurrences immediately below and adjacent to the infiltration lagoon. Positive total coliform counts were found for three sampling rounds in near downgradient wells 32010 and 32020 but randomly occurred in other wells beneath and farther downgradient from the stormwater basin. Also, positive fecal coliform counts were obtained from wells 32030, 32040, and 32050 on the first round only. This could have been the result of contamination during construction. Positive fecal coliform counts were not obtained from wells beneath and downgradient from the stormwater basin, except on the last round at well 32180. This sample was likely contaminated.

Fecal coliforms were found only once in one of the two deep wells, 32120, immediately adjacent to the infiltration lagoon.

SOILS

Alluvium soil samples from both the saturated and unsaturated zones in the test and control areas were obtained in October, 1976. The location and depth of the soil samples are shown in Table 6. The depths below ground surface were used to delineate between different soil samples taken from the same well. Because of the large topographic changes between well locations,





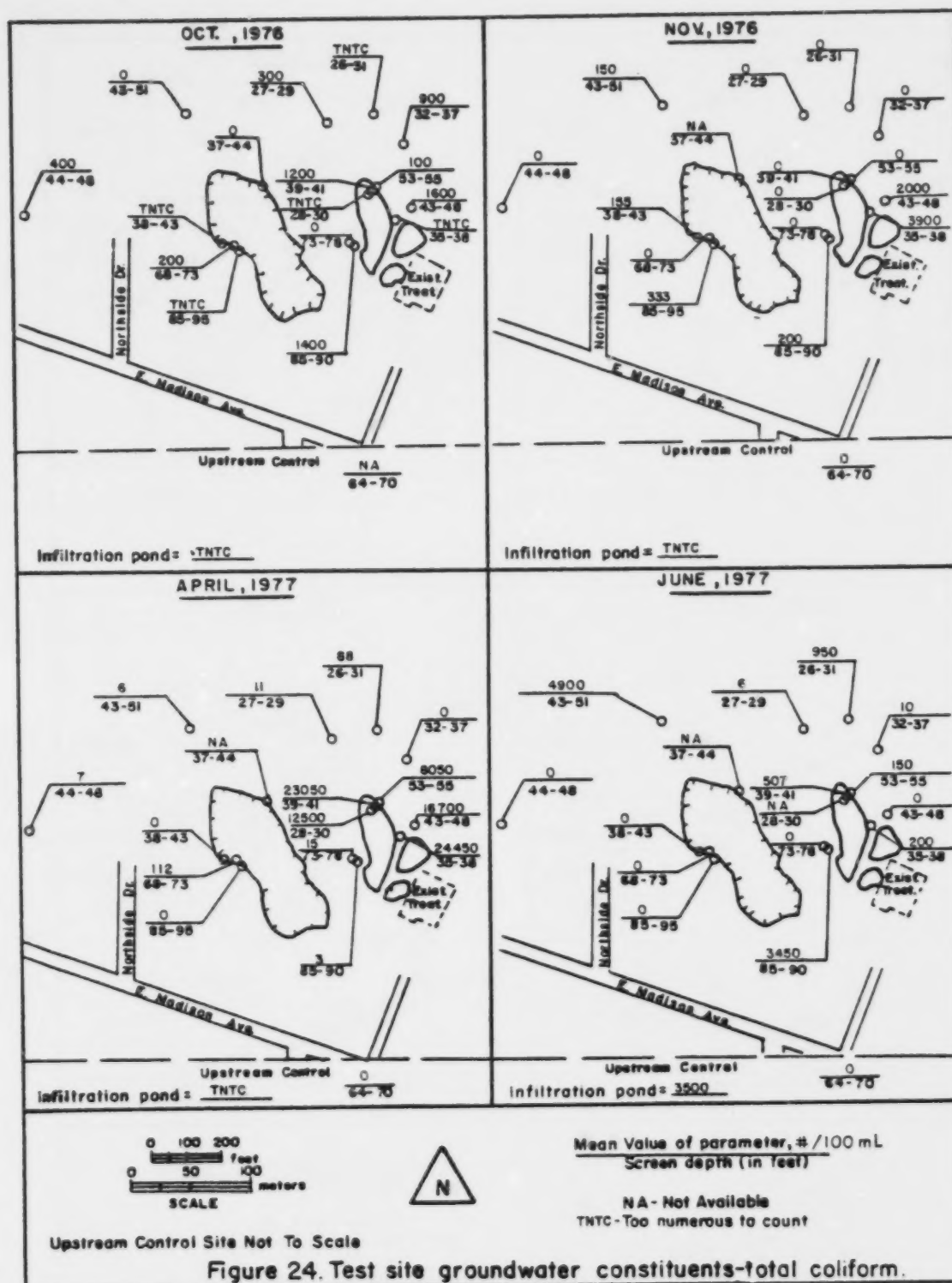
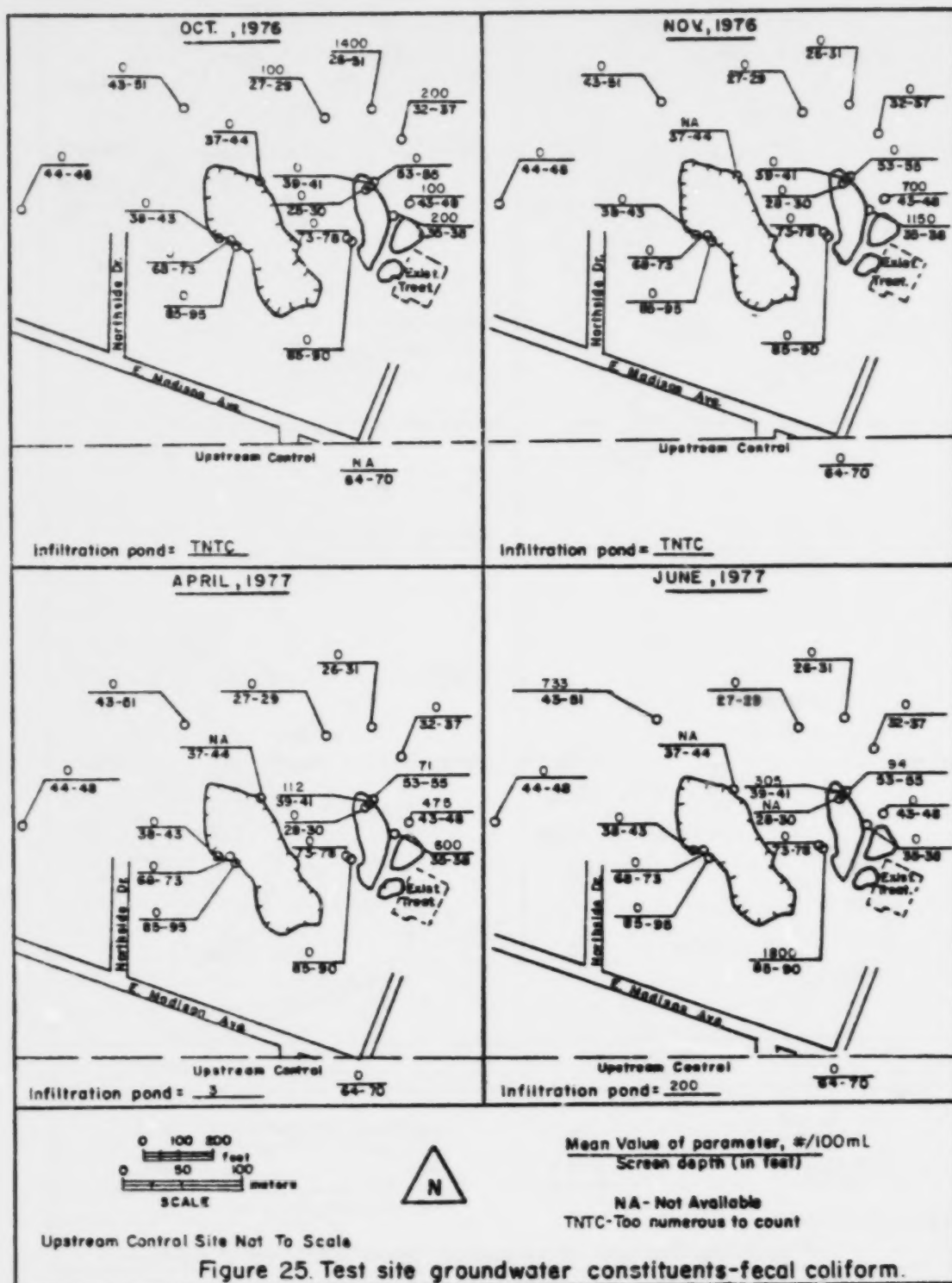


Figure 24. Test site groundwater constituents-total coliform.



the depth below ground surface varied considerably and tended to be confusing. Depths below lagoon bottom and depths below water table were much more significant to data evaluation. These relationships are shown on Figures 26 and 27.

Samples 324101, 324091, 324092, 324093, 324094, 324095, and 324102 were taken beneath the surface of the infiltration lagoon bottom, at successively deeper depths. Figure 26 is a profile of selected parameters for these samples.

Samples 324051, 324161, and 324191 denote downgradient test area alluvium samples. The sequence 314061, 324093, 324051, 324161, and 324191 provided a profile beginning in the control area alluvium and proceeding through the infiltration lagoon source alluvium to downgradient test alluvium, all at depths just below the water table. Profile I on Figure 27 illustrates this for selected parameters.

Samples 324095, 324102, 324121, 324122, and 324123 (Profile II, Figure 27) denote alluvium samples at 5 to 18 m (16 to 60 ft) below the water table immediately below and downgradient from the infiltration lagoon. Sample 314062 represents a control area alluvium sample at 4 m (14 ft) below the water table.

Profile II generally represented the deeper and probably less permeable alluvium soils as contrasted to the more permeable zone just below the water table depicted in Profile I. Selected alluvium data plotted for the above profiles include total nitrogen, total phosphorus, total arsenic, and total zinc.

The profile in the unsaturated zone below the lagoon bottom (Figure 26) shows selected parameters to initially decrease with increasing alluvium depth. As the examinations proceeded to greater depths below the water table, the data were less regular, making it difficult to distinguish data scatter from possible trends due to changing permeabilities and irregularities in the groundwater flow net. If the data scatter at greater depths were random, it would then appear that the zinc, nitrogen, and phosphorus data became generally asymptotic to the background concentrations observed in the control alluvium. Arsenic, as discussed earlier, was the one parameter that appeared to decrease with alluvium depth to a residual concentration less than that observed for the control alluvium. A possible explanation for this behavior was the reduction of arsenic to a soluble form that was free to migrate through the test alluvium. Because most adsorption sites were occupied by orthophosphate phosphorus, arsenic retention in the soil was minimal.

Profile I on Figure 27 demonstrates the same characteristics as Figure 26. The selected parameters showed variability in proximity to the infiltration lagoon but, with the exception of arsenic, approached the background concentrations of the control alluvium as the groundwater flow moved farther away. Again, arsenic concentrations appeared to be less in the test than in the control alluvium. Similar behavior was previously observed for manganese and iron.

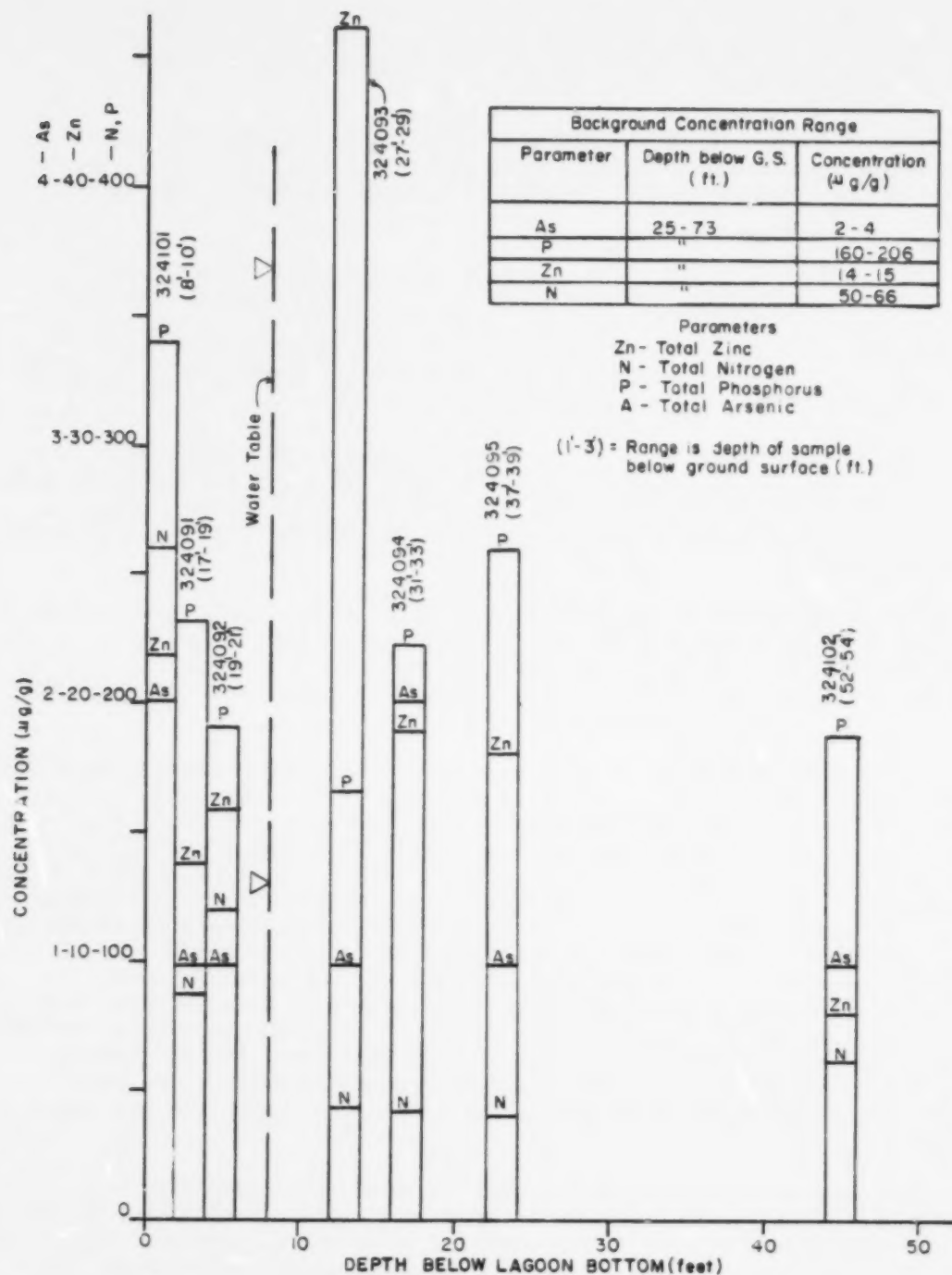


Figure 26. Profile of selected parameters in the alluvium beneath the infiltration lagoons.

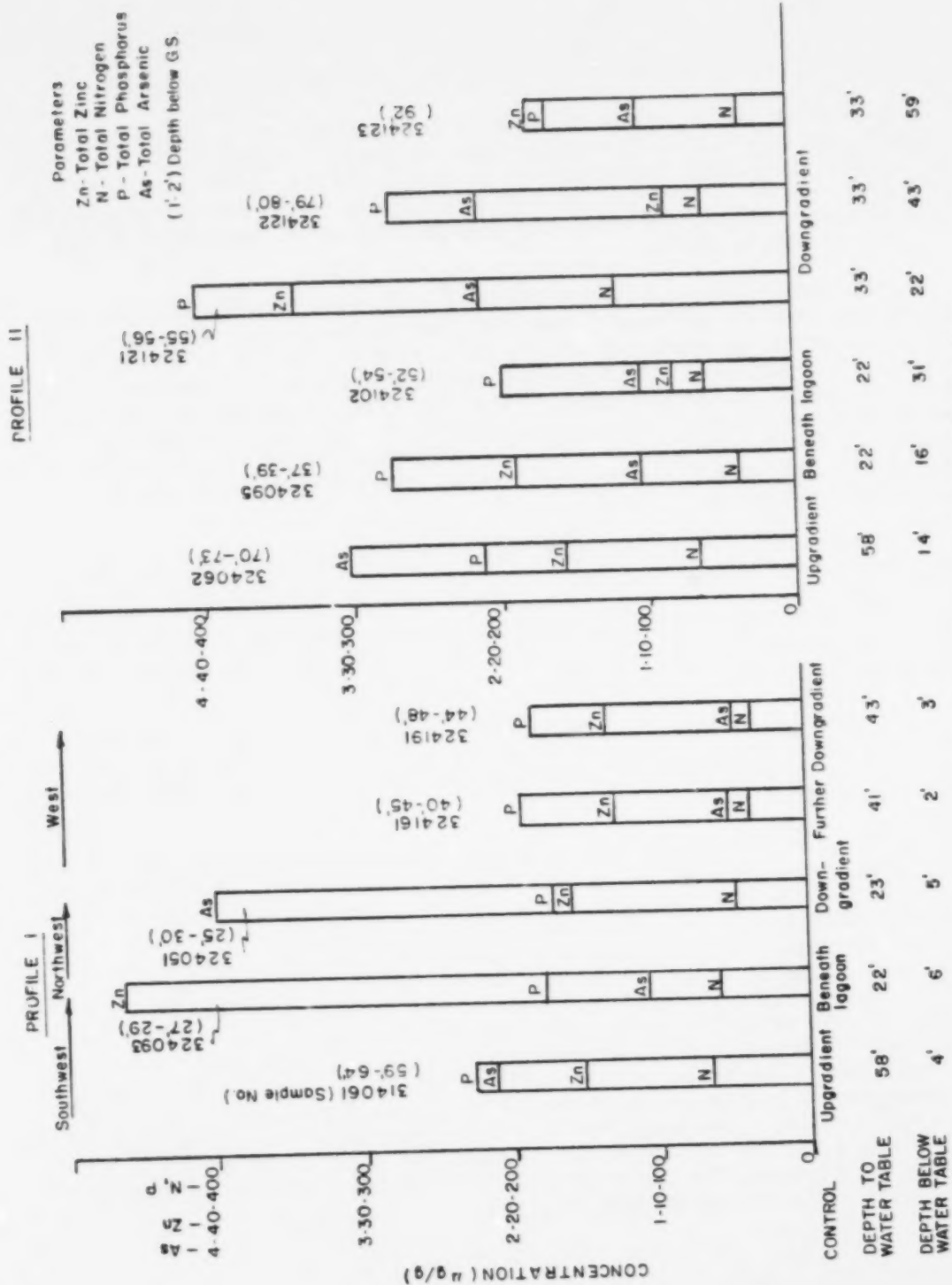


Figure 27. Profiles of selected parameters in the alluvium.

Observations concerning Profile II were similar to those made for Profile I and Figure 26. Parameter concentrations at these depths tended either to be less than control values or to decrease with depth. Arsenic again showed lower concentrations in the test than in the control alluvium.

In Profile II of Figure 27, lower concentrations of parameters are observed in samples 324095 and 324102 than in 324121. According to well logs, well 32120, at a depth corresponding to sample 324121, contained fines and more silty material than the wells from which the other two above-mentioned samples came. This could allow for greater absorptive capability at the location of sample 324121.

The overall observation concerning the alluvium constituents was that the accumulation of effluent parameters such as phosphorus, nitrogen, and zinc appeared to be localized within 150 m (500 ft) of the infiltration lagoons. Yet soluble orthophosphate phosphorus continued to escape beyond this perimeter. It would appear, therefore, that the permeable alluvium sediments were not very effective adsorbents for phosphorus under the conditions existing at Milton. The low dissolved oxygen concentrations in the groundwater indicated dominantly reducing conditions under which phosphorus remains more soluble.

Decreased flow rates of infiltrated water through the less permeable zones having the greater adsorptive capability would also account for the low phosphorus concentrations observed in the test groundwater at deeper depths in wells 32120, 32140, and 32150. At the same time, phosphorus continues to move downgradient through the more permeable, less absorptive sand and gravel zones.

The analytical results available for pesticides and herbicides indicated the presence of lindane at a concentration range of 250 to 1,116 ng/L and 2,4,5 TP silvex from 0.9 to 2.4 ng/L in the alluvium under the infiltration pond (Appendix B).

An statistical analysis of the sample data was performed to compare parameter mean concentrations in the soils beneath the control site with those in the soils beneath the test site. The control samples were identified by the numbers 314061 and 314062. Samples in the immediate vicinity of the infiltration lagoon at the test site were used in the analysis. These samples were numbers 324091, 324092, 324093, 324094, 324095, 324101, 324102, 324121, 324122, and 324123. The test and control site sample means are given in Table 16. The method of pooled variances was applied to the sample data to determine if significant differences between the parameter means existed at the 0.05 level. As shown in Table 16, the analysis revealed significant differences for available phosphorus, extractable copper, total chromium, and total arsenic. The means for available phosphorus and extractable copper were greater for the test site, while means for total chromium and total arsenic were greater for the control site. For the remaining parameters, no significant differences were detected.

TABLE 16. MEAN CONCENTRATIONS OF PARAMETERS IN
CONTROL AND TEST SITE SOILS

Parameter	Means ($\mu\text{g/g}$ unless noted)	
	Control	Test
pH (units)	8.9	8.7
Inorganic N	40.5	34.5
Total Organic N	22	51
Total Phosphorus	204	242
Available Phosphorus	1	10 ^a
Total Sulfur	75	250
Cation Exchange Capacity (meq/100g)	1	1
Extractable Aluminum	5.0 ^b	5.0 ^b
Extractable Boron	0.44 ^b	0.39
Extractable Cadmium	0.02 ^b	0.03
Exchangeable Calcium	1.77 ^b	1.82 ^b
Extractable Cobalt	0.12 ^b	0.12 ^b
Extractable Chromium	0.05 ^b	0.05 ^b
Extractable Copper	0.2	1.1 ^a
Extractable Iron	13	31
Extractable Lead	1.2 ^b	1.2 ^b
Exchangeable Magnesium (mg/g)	0.03	0.02
Extractable Mercury	8.0	15.8
Extractable Nickel	0.25 ^b	0.5
Exchangeable Potassium (mg/g)	0.01	0.02
Exchangeable Sodium (mg/g)	0.01 ^b	0.02
Extractable Zinc	0.45	3.50 ^b
Endrin (ng/g)		0.60 ^b
Lindane (ng/g)		582.8
Methoxychlor (ng/g)		0.01 ^b
Toxaphene (ng/g)		0.6 ^b
2,4-D (ng/g)		0.1 ^b
Silvex (ng/g)		1.7
Total Aluminum (mg/g)	3.6	3.7
Total Cadmium	2 ^b	2 ^b
Total Calcium (mg/g)	28	29
Total Cobalt	2 ^b	2 ^b
Total Chromium	12	9 ^a
Total Copper	5.5	5.7
Total Iron (mg/g)	3.1	2.9
Total Lead	10 ^b	10 ^b
Total Magnesium (mg/g)	6.1	5.5
Total Manganese	116	108
Total Mercury	1.0 ^b	1.0 ^b
Total Nickel	12.0	12.2
Total Potassium (mg/g)	5.0	4.8
Total Sodium (mg/g)	1.4	1.9
Total Zinc	15	20
Total Arsenic	3	1.40 ^a
Total Selenium	1	1

^a Test and control site means significantly different at the 0.05 level.

^b Average concentration below detection limit indicated.

PROJECTED USEFUL LIFE OF SITE FOR WASTEWATER INFILTRATION

The original intent of this study was to provide answers to a number of questions related to the long-term viability of land treatment systems. Two such questions discussed in the following paragraphs are:

1. For how long a period can a land treatment system be expected to provide satisfactory renovation treatment for wastewater?
2. What effect does continuing long-term application of organic, nitrogenous, and heavy metal constituents have on the soil and groundwater systems?

The Milton infiltration system has been discharging nitrogen constituents to the groundwater underlying the lagoons for some time. Ammonia nitrogen particularly was present in high concentrations. Based on the average infiltration lagoon and infiltrated groundwater total nitrogen concentrations, approximately 62 percent of the nitrogen applied left the site of the Milton treatment plant via the groundwater. Likewise, approximately 65 percent of the phosphorus left the site via the groundwater.

Phosphorus and nitrogen accumulations over background concentrations in the alluvium were approximately 18,000 and 14,000 kg (40,000 and 30,000 lb), respectively. Phosphorus was no longer accumulating in the site soils to the degree it apparently once did. The present phosphorus accumulation rate in site soils was in the range of 600 kg (1,300 lb) per year as contrasted with the historical estimate of 1,200 kg (2,700 lb) per year. These are rough estimates based upon sparse available data, and the differences could be much smaller than are herein indicated.

Metal constituents were being removed effectively within a 150-meter (500-foot) radius of the infiltration lagoon. Assuming that performance is proportional to the region of new interfacial alluvium area, a 100-year life for continuing metal removal could possibly require an alluvial area within a 900-meter radius of the infiltration lagoon.

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APPENDIX A

WELL LOGS FOR CONTROL AND TEST SITES

Milton, Wisconsin

Drill Hole Logs

Control Site

Hole 31060

Date: 11-15-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 64 ft.
Screen: 2 in. slotted (0.020 in.) plastic 64 to 70 ft.

Remarks: Drilled with bentonite to 60 ft., drove 4 in. steel casing to 53 ft., cleaned hole with clear water and drilled with clear water to 70 ft. Hole sealed with bentonite slurry and steel pipe pulled.

Log: Depth in Feet

0-3	Silt, black
3-16	Sand, fine, silty, brown
16-51	Sand, fine to medium, with gravel, small boulders 30-33 ft.
51-56	Black stone chips
56-70	Sand, fine to medium, and gravel

Test Site

Hole 32010

Date: 9-25-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 35 ft.
Screen: 2 in. slotted (0.020 in.) plastic 35 to 38 ft.

Remarks: Drilled with bentonite to 30 ft., drove steel casing to 35 ft., cleaned hole with clear water, drove steel casing to 40 ft. Sand pack 34-38 ft., sealed with bentonite pellets and bentonite slurry, steel casing pulled. Split spoon sample taken at 20, 25, and 30 ft.

Log: Depth in Feet

0-12	Sand, fine to medium, light brown, with cobbles and small boulders
12-36	Sand, medium to coarse, light brown, fine gravel, some cobbles
36-40	Sand, fine, gray to black

(Continued)

Hole 32020

Date: 9-27-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 43 ft.
Screen: 2 in. slotted (0.020 in.) plastic 43 to 48 ft.

Remarks: Drilled with bentonite to 40 ft., flushed hole with clear water, drove steel casing to 48 ft., cleaned hole with clear water, sand pack 42-48 ft., sealed with bentonite pellets and bentonite slurry, steel casing pulled. Split spoon samples taken at 29, 34, and 39 ft.

Log: Depth in Feet

0-14	Sand, fine to medium, brown, medium to large gravel and few cobbles
14-16	Gravel, small
16-33	Sand, fine to medium, brown, some small gravel and occasional cobble
33-38	Sand, medium to coarse, with small gravel, occasional cobble
38-48	Sand, fine to medium, occasional fine gravel

Hole 32030

Date: 9-30-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 26 ft.
Screen: 2 in. slotted (0.020 in.) plastic 26 to 31 ft.

Remarks: Drilled with 6 in. hollow stem auger, sealed hole with bentonite. Split spoon sample at 29 ft.

Log: Depth in Feet

0-6	Sand, very fine to medium, silty, loose, brown
6-10	Sand, very fine to medium, silty, firm, tan
10-23	Sand, very fine to medium, silty, firm, orange, trace fine to medium gravel
23-27	Sand, fine to medium, silty, loose, brown, some fine gravel
27-32	Sand, very fine, silty, firm, tan, 6 in. stringer of coarse sand and gravel to 30 ft.

Hole 32040

Date: 10-1-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 32 ft.
Screen: 2 in. slotted (0.020 in.) plastic 32-38 ft.

Remarks: Drilled with 6 in. hollow stem auger, sealed hole with bentonite. Split spoon samples at 29, 34, 39, and 44 ft.

(Continued)

Log: Depth in Feet

0-28 Sand, very fine to medium, silty, firm, tan, occasional
gravel stringers
28-34 Sand, fine to coarse, silty, firm, brown
34-35 Sand, coarse, gravel
35-45 Sand, fine to coarse, silty

Hole 32050

Date: 10-1-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 27 ft.
Screen: 2 in. Johnson plastic 0.020 in. slot 27 to 29 ft.

Remarks: Drilled with 6 in. hollow stem auger, bentonite seal above
screen and at top of hole.

Log: Depth in Feet

0-25 Sand, fine to medium, silty, firm, brown, some large
cobbles
25-30 Sand, coarse, gravel fine to large, clean

Hole 32070

Date: 6-30-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 30 ft.
Screen: 2 in. saw-cut plastic 30 to 40 ft.

Remarks: Hollow stem auger to 7 ft., drilled with rotary and Revert
from 7 to 60 ft., sealed hole with bentonite and backfilled
with bentonite. Split spoon samples at 19 and 34 ft.

Log: Depth in Feet

0-16 Sand, fine, light brown, occasional cobbles
16-17 Gravel
17-19 Sand and gravel
19-30 Sand, medium to coarse, occasional cobbles
30-32 Sand and gravel
32-47 Sand, fine to coarse, gray, wastewater odor
47-60 Sand, very fine to fine

(Continued)

Hole 32080

Date: 10-2-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 28 ft.
Screen: 2 in. Johnson plastic 0.020 in. slot 28 to 30 ft.

Remarks: Augered to 7 ft., drilled with rotary using bentonite to 26 ft., flush hole with clear water, drove steel casing to 33 ft., flushed hole, sand pack 26-33 ft., sealed with bentonite, filled hole with bentonite slurry. Split spoon sample at 13, 15, 17, 22, and 31 ft.

Log: Depth in Feet

0-18	Fill, sand and cobbles
18-22	Sand, fine to medium, loose, organic
22-24	Sand, fine, black
24-26	Gravel, up to 1/2 in., clean
26-33	Sand, fine to coarse, black, organic, with small gravel

Hole 32090

Date: 10-2-76 Rig: Rotary-Auger
Casing: 2 in. plastic to 39 ft.
Screen: 2 in. Johnson plastic 0.020 in. slot 39 to 41 ft.

Remarks: Augered to 19 ft., drilled with rotary and bentonite to 35 ft., flushed hole clean and drove steel casing to 42 ft., flush hole, sand pack 37 to 42 ft., sealed with bentonite and filled hole with bentonite slurry. Split spoon sample at 15.5, 17, 19, 27, and 37 ft.

Log: Depth in Feet

0-16	Fill, sand and cobbles
16-30	Sand, fine to coarse, scattered pebbles
30-42	Sand, medium to coarse, some gravel layers

Hole 32100

Date: 10-3 to 5-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 53 ft.
Screen: 2 in. Johnson plastic 0.020 slot 53 to 55 ft.

Remarks: Augered to 10 ft., drilled with rotary and bentonite mud to 52 ft., drove steel casing 55 ft., clean hole, sand pack 51 to 55 ft., sealed with bentonite and filled hole with bentonite slurry.

(Continued)

Log: Depth in Feet

0-8	Fill, sand and cobbles
8-29	Sand, fine to medium, black, with fine to large gravel, sand became firmer with depth
29-48	Sand, very fine to medium, tan, dense, with gravel and cobbles
48-50	Sand with several thin clay stringers
50-55	Sand fine to medium, with gravel and cobbles

Hole 32110

Date: 9-28-76 Type Rig: Rotary-Augur

Casing: 2 in. plastic to 73 ft.

Screen: 2 in. slotted (0.020 in.) plastic 73-78 ft.

Remarks: Drilled with bentonite mud to 65 ft., washed hole with
clean water, drove steel pipe to 75 ft., drilled with clear
water to 80 ft., sealed with bentonite pellets and filled
hole with bentonite slurry. Split spoon samples at 50 ft.

Log: Depth in Feet

0-18	Sand, fine to medium, silty, brown, with cobbles
18-30	Sand, fine to coarse, brown, gravel and occasional cobbles
30-33	Gravel, fine to coarse, brown, with cobbles
33-40	Sand, fine to medium, brown, some gravel
40-42	Gravel, sandy
42-47	Sand, fine to medium, some gravel
47-61	Sand, fine, gray to brown, silty, some gravel near base
61-75	Sand, fine to medium, brown, with gravel
75-80	Sand, fine to medium, brown and gravel

Hole 32120

Date: 9-30 to 10-2-76 Type Rig: Rotary-Augur

Casing: 2 in. plastic to 85 ft.

Screen: 2 in. slotted (0.020 in.) plastic 85 to 90 ft.

Remarks: Drilled with rotary and bentonite mud to 85 ft., drove
steel casing to 95 ft., flushed hole with clear water,
sand pack 83 to 90 ft., sealed with bentonite, filled
hole with bentonite slurry. Split spoon samples at 55
and 80 ft.

(Continued)

Log: Depth in Feet

0-30	Sand, fine to medium, brown, silty lenses, gravel, occasional cobbles and small boulders
30-35	Sand, fine to medium, brown, and gravel with cobbles
35-52	Sand, fine to medium, brown, some gravel and occasional cobbles, more gravel near base
52-84	Sand, very fine to fine, gray-brown, silty lenses, occasional gravel streaks
85-95	Sand, fine, brown, limestone chips

Hole 32130

Date: 9-30-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 37 ft.
Screen: 2 in. slotted (0.020 in.) plastic 37 to 43 ft.

Remarks: Drilled 6 in. hollow stem auger, sealed with bentonite.

Log: Depth in Feet

0-6	Soil, silty, clayey, black and organic
6-9	Clay, soft, gray, silty to slightly sandy
9-13	Sand, very fine to medium, gray, many clay stringers
13-27	Sand, fine to medium, brown, silty, some fine to medium gravel, scattered large gravel and cobbles
27-38	Sand, fine to medium, brown, slightly silty, some fine to medium gravel
38-45	Sand, medium to coarse, tan, silty, with fine to medium gravel

Hole 32140

Date: 9-27-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 69 ft.
Screen: 2 in. slotted (0.020 in.) plastic 69 to 74 ft.

Remarks: Drilled with 6 in. hollow stem auger, sand pack, sealed with bentonite. Split spoon samples at 44, 46, 60, 68, 73.5, and 78 ft.

(Continued)

Log: Depth in Feet

0-2	Mud, black organic
2-6	Clay, black
6-7	Clay, sandy
7-10	Sand, gray, silty
10-41	Sand, fine to medium, brown, silty
41-45	Gravel, coarse, and cobbles, very silty, with clay stringers
45-48	Clay
48-60	Gravel and cobbles, dirty
60-63	Sand, coarse, clean
63-67	Sand, fine, silty
67-74	Sand, fine and gravel, fine, dirty with clay stringers
74-75	Gravel and cobbles, dirty

Hole 32150

Date: 9-28-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 85 ft.
Screen: 2 in. slotted (0.020 in.) plastic 85 to 95 ft.

Remarks: Drilled with 6 in. hollow stem auger to 45 ft., drilled with rotary and bentonite mud to 65 ft., drove steel casing then drilled with clear water to 97 ft., cored 90 to 95.5 ft.

Log: Depth in Feet

0-5	Mud, silty, soft, organic
5-8	Clay, silty, soft, gray, trace fine sand
8-12	Clay and sand, fine to medium, silty, with clay stringers
12-42	Sand, fine to medium, silty, some fine to medium gravel and scattered large gravel
42-59	Sand, fine to coarse, silty, tan, with fine to medium gravel
59-65	Sand, very fine to medium, silty and clayey, scattered fine to medium gravel
65-80	Sand, very fine to medium, silty, clayey, fine to large gravel, scattered cobbles
80-97	Limestone, white, fractured

Hole 32160

Date: 10-6-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 37 ft.
Screen: 2 in. slotted (0.020 in.) plastic 37 to 44 ft.

Remarks: Drilled with 6 in. hollow stem auger, sealed with bentonite. Installed automatic water level recorder.

(Continued)

Log: Depth in Feet

0-6	Silty, sandy, black
6-11	Sand, very fine, silty, brown, occasional fine gravel
11-16	Sand, fine, light brown, occasional fine gravel
16-19	Sand, fine, silty, reddish brown, occasional clay stringers
19-24	Gravel and cobbles
24-45	Sand, fine to medium, brown, trace of silty, with gravel and cobbles

Hole 32170

Date: 9-21-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 74 ft.
Screen: 2 in. slotted (0.020 in.) plastic 74 to 89 ft.

Remarks: Drilled with rotary and bentonite mud to 89 ft., flushed with clear water, drilled with clear water to 100 ft., caved back to 90 ft. Sealed with bentonite.

Log: Depth in Feet

0-5	Silty, black
5-11	Clay, silty, light brown
11-14	Sand and gravel, some clay
14-35	Sand, fine to coarse, gravel, occasional cobbles near base
35-51	Limestone chips, hard
51-61	Sand, fine to medium, brown
61-68	Sand, and boulders
68-90	Sand, occasional cobbles and several boulders
90-100	? no sample return

Hole 32180

Date: 10-5-76 Type Rig: Rotary-Auger
Casing: 2 in. plastic to 43.5 ft.
Screen: 2 in. slotted (0.020 in.) plastic 43.5 to 51.5 ft.

Remarks: Drilled with 6 in. hollow stem auger, sealed with bentonite.

Log: Depth in Feet

0-7	Silty, sandy, brown
7-11	Sand, very fine, light brown
11-29	Sand, fine to medium, brown, trace of silty, gravel
29-37	Sand, fine, light brown, occasional cobbles
37-50	Sand, fine to medium, brown, fine to medium gravel
50-55	Sand, fine, silty

(Continued)

Hole 32190

Date: 10-4-77 Type Rig: Rotary-Augur
Casing: 2 in. plastic to 44 ft.
Screen: 2 in. slotted (0.020 in.) plastic 44 to 53 ft.

Remarks: Drilled with 6 in. hollow stem auger, sealed with bentonite.
Split spoon samples at 40, 45, and 55 ft.

Log: Depth in Feet

0-6	Silty, clayey, brown
6-12	Sand, medium, silty, red-brown, occasional gravel
12-26	Sand, medium, light brown, trace of silt
26-32	Sand, fine to medium, brown, fine to coarse gravel, occasional small cobbles, silty
32-42	Sand, fine to medium, light brown, gravel and occasional cobbles, clean
42-47	Sand, fine to medium, light brown, and gravel, fine
47-54	Silt, clayey, light brown

Hole 32200

Date: 9-23 to 24-76 Type Rig: Rotary-Augur
Casing: 2 in. plastic to 77 ft.
Screen: 2 in. Johnson plastic (0.020 in.) slot 77 to 79 ft.

Remarks: Drilled with rotary and bentonite mud to 80 ft., flushed hole, drilled with clear water to 85 ft., hole caved, sealed with bentonite.

Log: Depth in Feet

0-3	Silty, clayey, brown
3-7	Sand, fine to medium, some coarse, silty brown
7-9	Cobbles and sand
9-31	Sand, fine to medium, trace of silt
31-46	Sand, fine to coarse, brown, gravel, large occasional cobble layer
46-73	Sand, fine, brown, occasional fine gravel, with boulders at base
73-80	Sand, fine, light brown, some gravel
80-85	Sand and gravel

APPENDIX B

DATA TABLES FOR ALL WATER AND SOIL SAMPLES

LEGEND

Sample code numbers are explained in Section 7, "Results and Discussion."

99.9 means too numerous to count.

Negative sign (-) means less than.

Values in $\mu\text{g/g} \times 10^{-4}$ = percentage.

TABLE B-1. WATER QUALITY DATA

SAMPLE NUMBER	COLLECTION DATE	DEPTH, FT.	TEMP, DEG. C.	DISSOLVED OXYGEN, MG/L	PH	CONDUCTIVITY, MICRO/CM	TOTAL ALKALINITY, MG/L CaCO ₃	DISSOLVED SOLIDS, MG/L	SUSPENDED SOLIDS, MG/L	TOTAL SOLIDS, MG/L	VOLATILE SUSPENDED SOLIDS, MG/L	BOD, MG/L	COD, MG/L	CL, MG/L
312101	10/ 5/76			5.6	7.6	754	336	413				-1	36	16
312102	11/16/76			7.5	7.8	756	328	430				2	4	12
312104	6/22/77			7.7	7.6	769	360	472				1	3	28
316002	11/15/76			4.4	8.0	655	276	347				-1	12	6
316003	4/10/77			4.3	7.6	523	304	329	2	331		-1	6	3
316002	11/17/76	20.4		3.2	7.7	607	228	359				3	12	17
316003	4/ 8/77	20.4	10.0	9.4	7.7	559	216	381				16	37	23
316004	6/22/77	20.4	15.0	8.5	7.9	618	226	377				1		39
324401	10/ 5/76			8.2	7.4	164	48	124	28	152	18	12	58	4
324402	11/16/76			16.1	8.1	231	80	118	5	123	5	6	28	12
324403	4/ 7/77		10.0	13.5	8.2	139	32	114	10	124	5		30	
324404	6/22/77			12.0	9.4	255	96	258	25	283	15	18	97	50
324501	10/ 5/76			2.2	7.6	1404	372	568	16	684	4		52	174
324502	11/16/76			1.4	7.7	1509	448	748	31	779	11	5	63	176
324503	4/ 8/77			3.0	7.6	1449	388	805	33	838	7	39	82	227
324504	6/21/77		22.0	20.0	8.8	1365	416	764	19	783	12	26	49	173
324505	6/22/77		22.0	22.6	8.9	1307	412					20	68	192
324601	10/ 6/76			3.6	7.7	1366	382	608	22	630	10		48	216
324602	11/17/76			3.6	7.5	1451	428	705	37	742	32	12	112	164
324603	4/ 7/77			4.0	7.6	1312	412	734	11	745	7	19	64	184
324604	6/22/77			3.4	8.0	1596	416	866	45	911	36	52	112	235
320101	10/ 5/76	11.1		2.0	7.2	1357	364	705				4	28	189
320102	11/15/76	11.1		0.5	7.4	1465	436	736				2	28	182
320103	4/ 7/77	11.1	10.0	1.4	7.3	1364	392	760				9	29	199
320104	6/21/77	11.1	18.0	3.4	7.4	1534	501	760				6	21	177

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP. DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUCT- IVITY UMHOS/CM	TOTAL ALKALINITY MG/L CaCO ₃	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	VOLEATILE SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
320201	10/ 5/76	13.9		2.5	7.5	1357	410.	711.			4.	24.	174.
320202	11/16/76	13.9		0.7	7.4	1416.	452.	737.			3.	16.	200.
320203	4/ 7/77	13.9	8.0	0.6	7.5	1332.	410.	753.			9.	30.	161.
320204	6/21/77	13.9	17.0	1.7	7.5	1478.	495.	739.			8.	25.	190.
321101	10/ 5/76	23.0		0.5	7.5	1363.	434.	670.			1.	34.	216.
321102	11/15/76	23.0		0.5	7.6	1436.	436.	727.			1.	28.	182.
321103	4/10/77	23.0	12.0	1.4	7.5	1300.	412.	704.			6.	27.	152.
321104	6/21/77	23.0	15.0		7.6	1440.	430.	758.			7.	18.	183.
321201	10/ 5/76	26.7		0.4	7.5	1176.	424.	579.			3.	32.	140.
321202	11/15/76	26.7		0.4	7.6	1221.	416.	565.			1.	28.	
321203	4/10/77	26.7	15.0	-0.1	7.5	1221.	428.	599.			2.	26.	131.
321204	6/23/77	26.7	13.0		7.8	1215.	393.	645.			8.	18.	162.
320801	10/ 7/76	8.8		0.2	7.4	1584.	386.	793.			3.	44.	174.
320802	11/16/76	8.8		-0.1	7.7	1483.	452.	747.			-1.	28.	182.
320803	4/10/77	8.8	10.0	0.1	7.5	1208.	428.	716.			7.	41.	186.
320804	6/23/77	8.8									199.		
320901	10/ 7/76	12.2		0.7	7.3	1392.	420.	683.			2.	40.	174.
320902	11/16/76	12.2		0.7	7.5	1476.	440.	734.			1.	12.	183.
320903	4/ 9/77	12.2	10.0	0.7	7.5	1336.	436.	729.			9.	44.	203.
320904	6/22/77	12.2		1.8		1508.		685.			19.	62.	
321001	10/ 5/76	16.3		3.5	7.6	1344.	422.	594.			3.	36.	174.
321002	11/16/76	16.3		0.9	7.7	1414.	424.	702.			-1.	16.	181.
321003	4/ 9/77	16.3		1.7	7.7	1349.	432.	747.			7.	34.	
321004	6/22/77	16.3				1470.					14.	37.	187.
320301	10/ 6/76	0.7		1.6	7.3	1096.	434.	578.			72.	95.	

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUCTIVITY UMHS/CM	TOTAL ALKALINITY MG/L CaCO ₃	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	TOTAL SOLIDS MG/L	VOLATILE SUSPENDED SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
320302	11/15/76	8.7		2.7	7.8	1096.	368.	574				-1.	18.	145.
320303	4/ 7/77	8.7	12.0	0.8	7.4	1330.	388.	749.				2.	10.	177.
320304	6-21/77	0.7	12.0	2.5	7.5	1440.	428.	813.					74.	34.
320401	10/ 6/76	10.7		1.9	7.4	838.	378.	418.				3.	4.	56.
320402	11/16/76	10.7		2.1	7.8	882.	344.	478.				2.	16.	154.
320403	4/ 8/77	10.7		0.8	7.3	1290.	356.	721.				2.	10.	176.
320404	6-21/77	10.7	10.0	2.3	7.4	1366.	430.	786.				-1.	68.	142.
320501	10/ 6/76	8.5		1.5	7.3	1276.	394.	686.				-1.	20.	179.
320502	11/15/76	8.5		3.2	7.5	1328.	412.	686.				1.	20.	160.
320503	4/ 7/77	8.5	10.0	1.4	7.5	1361.	384.	764.				2.	15.	173.
320504	6-21/77	8.5		1.8	7.6	1470.	470.	775.					160.	95.
321301	10/ 6/76	12.6		0.6	7.4	1119.	358.	605.				1.	16.	119.
321302	11/17/76	12.6		-0.1	7.6	1156.	380.	591.				2.	20.	77.
321303	4/ 9/77	12.6	10.0	1.4	7.3	753.	314.	467.				2.	14.	108.
321304	6-23/77		11.0	1.1	7.4	898.	265.	524.				14.	72.	95.
321401	10/ 7/76	21.8		0.9	7.5	1107.	390.	562.				-1.	16.	95.
321402	11/17/76	21.8		0.6	7.5	1260.	428.	575.				1.	18.	69.
321403	4/ 9/77	21.8	12.0	-0.1	7.6	1008.	380.	488.				7.	29.	120.
321404	6-23/77			0.2		1010.		540.				13.	40.	95.
321501	10/ 6/76	27.4		0.9	7.4	1230.	442.	636.				-1.	20.	148.
321502	11/17/76	27.4		0.5	7.6	1260.	436.	640.				4.	23.	129.
321503	4/ 9/77	27.4	12.0	0.1	7.4	1118.	400.	627.				6.	14.	152.
321504	6-23/77		12.0		7.5	1232.	451.	598.				4.	10.	142.
321601	10/ 7/76	12.3		1.2	7.6	1392.	370.	710.				6.	20.	142.
321602	11/17/76	14.3		3.1	7.7	1290.	396.	694.				-1.	34.	195.
321603	4/ 8/77	14.3	10.0	3.2	7.4	1366.	388.	687.				2.	14.	156.
321604	6-23/77		8.0	1.2	7.3	1270.	380.	750.				4.	11.	167.
321901	10/ 6/76	14.5		2.2	7.5	1345.	430.	764.				16.	95.	
321902	11/17/76	14.5		1.5	7.4	1197.	394.	614.				-1.	20.	156.
321903	4/ 8/77	14.5	15.0	0.7	7.3	1264.	356.	614.				3.	10.	147.
321904	6-23/77			3.6	7.4	1168.	348.	671.				14.	21.	192.
				1.3	7.4	1197.	349.	723.						

(continued)

TABLE B-1. Continued

SAMPLE NUMBER	SULFIDE MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L-C	DISSOLVED ORGANIC CARBON MG/L-C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO- PHOSPHATE MG/L-P
312101		100.	0.		15.2			0.1	5.5		0.06	0.04
312102		0.	0.			1.2		0.2	4.4		0.02	0.02
312104		0.	0.		3.5	-0.1		0.2	4.3		0.06	0.02
316002		0.	0.			0.2		0.2	1.7		-0.01	-0.01
316003	-0.1	0.	0.		1.3	-0.1		-0.1	0.5		0.04	0.03
316002		0.	0.			0.3		0.1	9.6		-0.01	-0.01
316003	-0.1	0.	0.		13.7	1.0		0.2	7.7		0.24	0.20
316004		0.	0.		11.7	0.1		0.6	8.4		0.07	0.04
324401		99.9	99.9	13.0	12.0			0.2	2.5	3.90	3.40	2.90
324402		0.	0.			1.0		0.8	2.6	0.12	0.07	-0.01
324403	-0.1	800.	0.	20.0	18.8	-0.1		-0.1	-0.1	0.09	0.09	0.03
324404		1133	134	43.3	27.3	2.0		-0.1	-0.1	4.00	3.90	3.30
324501		99.9	99.9	12.7	8.0			14.6	10.0	7.20	6.40	5.20
324502		99.9	99.9	53.0	54.7	4.8		30.2		0.97	0.90	0.81
324503	-0.1	99.9	3.	8.1	39.8	-0.1		13.3	2.6	7.50	6.80	6.30
324504		3500.	200.	22.0	19.4	3.5		18.6	1.0	5.90	5.10	4.70
324505		1487.	235	37.5	12.8	5.3		19.2	1.4	5.70	4.70	4.10
324601		99.9	99.9	19.5	12.8			10.0	12.6	7.70	7.70	6.90
324602		0.	0.	61.0	50.2	7.4		25.6	5.0	9.50	8.50	7.00
324603	-0.1	99.9	0.	27.0	27.0	-0.1		20.1	1.0	8.40	8.40	8.00
324604		99.9	99.9	27.4	20.9	12.0		21.8	2.4	7.10	6.40	6.00
320101	-0.1	99.9	200.		9.1	3.8		9.9	0.4		5.70	5.70
320102		3900.	1150.			-0.1		19.8	3.2		7.20	7.20
320103	-0.1	4450.	600.			-0.1		16.7	-0.1		5.00	4.80
320104		500.	0.	18.4		-0.1		33.9	-0.1		12.00	12.00

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	SOLUBLE SULFUR MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L -C	DISSOLVED ORGANIC CARBON MG/L -C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO-PHOSPHATE MG/L-P
320201		1600	100		9.1			11.1	1.0		8.10	7.50
320202		2000	700				-0.1	16.0	2.9		10.00	8.90
320203	0.7	6700	475				-0.1	17.0	0.1		6.70	6.30
320204		0	0		19.0		0.1	34.1	-0.1		9.70	9.40
321101		0	0		6.1			21.5	1.3		3.70	3.40
321102		0	0				-0.1	23.0	1.7		3.40	3.40
321103	-0.1	15	0				-0.1	12.6	0.1		3.10	3.10
321104		0	0		6.2			21.0	0.1		3.20	3.20
321201		1400	0		6.6			24.1	0.3		0.06	0.04
321202		200	0				-0.1	30.0	2.5		0.12	0.07
321203	-0.1	3	0		25.5		0.1	19.5	-0.1		0.06	0.06
321204		3450	1800		8.4		-0.1	24.3	-0.1		0.20	0.15
320601		99.9	0		6.4			0.1	1.5		5.00	4.20
320602		0	0				-0.1	24.0	1.6		2.50	2.20
320603	1.6	2500	0		32.4		-0.1	18.5	0.1		8.90	8.90
320604		7707	7707		65.9		-0.1	35.4	0.2		14.00	10.20
320901		1200	0		8.2			9.9	1.2		13.00	7.00
320902		0	0				7.0	12.4	1.3		1.20	1.20
320903	1.0	3050	112		20.4		-0.1	19.8	-0.1		7.50	7.30
320904		507	305		24.1		-0.1	31.9	0.2		8.60	8.40
321001		100	0		9.2			20.2	1.5		6.00	3.50
321002		0	0				5.0	20.6	1.8		5.90	5.90
321003	0.2	8050	71		29.3		-0.1	11.3	-0.1		5.30	5.00
321004		150	94		20.0		-0.1	29.1	-0.1		9.60	9.60
320201		99.9	1400		27.9			3.9	3.2		2.90	2.90

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	SUBSTRATE MG/L-G	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL DISSOLVED CARBON MG/L-G	DISOLVED ORGANIC CARBON MG/L-G	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHOPHOSPHATE MG/L-P
320302		0	0				0.8	2.0	1.8	2.90	2.90	2.60
320303	-0.1	88	0			-0.1	6.9	0.5		3.00	3.00	2.90
320304		956	0			6.1	16.8	0.4		3.40	3.40	3.20
320401		900	200	27.0			10.0	5.6		1.30	1.30	1.20
320402		0	0			2.5	4.2	2.2		3.40	3.40	3.40
320403	-0.1	0	0	9.3		-0.1	6.9	0.8		3.20	3.20	3.00
320404		10	0	3.5			4.2	-0.1		3.10	3.10	2.90
320501		300	100	20.0			6.3	5.6		3.70	3.70	3.40
320502		0	0				10.1	2.6		3.40	3.40	3.20
320503	-0.1	11	0			-0.1	9.2	0.3		5.30	5.30	0.30
320504		6	0	10.6		0.6	19.3	0.3		2.00	2.00	1.90
321301		99.9	0	24.2			3.9	8.3		3.70	3.70	3.20
321302		166	0			-0.1	4.5			5.40	5.40	5.10
321303	-0.1	0	0	12.2		1.0	0.8	0.8		2.60	2.60	2.50
321304		0	0	6.6		1.4	3.4	0.4		2.40	2.40	2.20
321401		200	0	15.6			11.9	1.9		0.14	0.14	0.10
321402		0	0			-0.1	12.5			0.19	0.19	0.19
321403	-0.1	112	0			-0.1	8.2	-0.1		0.04	0.04	0.03
321404		0	0	8.5		2.9	19.5	0.1		0.26	0.26	0.24
321501		99.9	0	17.2			12.5	3.2		0.04	0.04	0.04
321502		333	0			0.1	13.0			0.09	0.09	0.04
321503	-0.1	0	0	17.5		2.6	8.0	-0.1		0.06	0.06	0.06
321504		0	0	10.0		2.4	13.2	-0.1		0.19	0.19	0.14
321601		0	0	6.9			5.8	3.1		3.20	3.20	2.60
321801		0	0	3.7			9.9	1.9		2.20	2.20	1.70
321802		150	0			-0.1	12.4			3.70	3.70	3.20
321803	-0.1	6	0			0.0	-0.1	7.0	0.1	2.80	2.80	2.70
221804		4900	733			0.0	-0.1	10.4	-0.1	4.10	4.10	3.90
321901		400	0	3.2		0.0	10.0	3.2		1.90	1.90	1.40
321902		0	0			0.0	7.0	8.6		2.90	2.90	2.70
321903	-0.1	7	0			0.0	-0.1	2.8	3.8	2.50	2.50	2.30
321904		0	0			0.0	0.7	2.1	10.3	2.90	2.90	2.60

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	SO ₄ MG/L	AL MG/L	AS UG/L	B UG/L	CD UG/L	CA MG/L	CO UG/L	CR UG/L	CU UG/L	FE MG/L	PB UG/L	MG MG/L	MN MG/L
312101	44	-0.3	-10	395	-20	132.0	-50	-20	-20	-0.2	-100	46.0	-0.05
312102	44	0.4	-10	288	-20	81.0	-50	-50	24	-0.1	-100	36.0	-0.05
312104	42	-0.3	-10	47	-20	95.0	-50	-20	-20	-0.2	-100	40.0	-0.05
316002	25	0.3	-10	69	-20	76.0	-50	-50	30	-0.1	-100	33.0	-0.05
316003	17	-1.0	-10	304	-20	67.0	-20	-50	-100	-0.5	-200	36.0	-0.05
316002	50	1.5	-10	232	-20	66.0	-50	-50	135	1.2	-100	38.0	-0.10
316003	35	-1.0	-10	219	-20	57.0	-20	-50	-100	-0.5	-200	32.0	-0.10
316004	43	-0.3	-10	222	-20	73.0	-50	-20	-20	-0.2	-100	30.0	-0.05
324401	12	-0.3	-10	256	-20	5.0	-50	-50	-20	-0.2	-100	6.0	-0.05
324402	17	0.7	-10	41	-20	10.0	-20	-50	-100	0.2	-200	1.0	-0.05
324503	19	-1.0	-10	38	-20	23.0	-20	-20	-20	-0.5	-200	3.0	-0.10
324504	5	-0.3	-10	897	-20	60.0	-50	-20	-20	1.1	-100	6.0	0.10
324501	59	0.4	14	665	-20	54.0	-50	-50	-20	-0.2	-100	40.0	0.06
324502	61	-1.0	-10	475	-20	80.0	-20	-50	-20	-0.1	-100	34.0	-0.05
324503	57	-0.3	-10	602	-20	63.0	-20	-50	-100	-0.5	-200	36.0	-0.10
324504	53	-0.3	-10	823	-20	58.0	-50	-20	-20	-0.2	-100	34.0	-0.05
324601	54	0.4	18	669	-20	73.0	-50	-50	-20	0.2	-100	40.0	-0.05
324602	48	-1.0	11	597	-20	75.0	-20	-50	-100	-0.2	-100	35.0	0.00
324603	47	-0.3	-10	636	-20	74.0	-50	-20	-20	0.4	-100	36.0	-0.10
324604	45	0.9	-10	518	-20	53.0	-50	-20	-20	-0.5	-200	35.0	-0.05
320101	75	-1.0	-10	623	-20	64.0	-20	-50	-100	1.4	-100	41.0	0.09
320102	16	-0.3	-10	562	-20	89.0	-50	-20	-20	2.9	-100	48.0	0.36
320103					-20		-20	-50	-100	3.0	-200	38.0	0.46
320104					-20		-20	-50	-100		-200	30.0	0.14

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	SO4 MG/L-SO4	AL MG/L-AL	AS UG/L-AS	B UG/L-B	CD UG/L-CD	CA MG/L-CA	CO UG/L-CO	CR UG/L-CR	CU UG/L-CU	FE MG/L-FE	PB UG/L-PB	MG MG/L-MG	MN MG/L-MN
320201	27	0.3	15	529	-20	58.0	-50	-20	-20	1.3	-100	46.0	0.19
320202	25	0.8	-10	772	-20	58.0	-50	-50	-20	1.4	-100	38.0	0.29
320203	41	-1.0	-10	602	-20	82.0	-20	-50	-100	2.1	-200	39.0	0.30
320204	14	-0.3	16	639	-20	80.0	-20	-20	-20	1.2	-100	34.0	0.22
321101	21	3.5	460	653	-20	129.0	-50	-20	33	3.6	-100	83.0	0.16
321102	22	1.2	42	576	-20	108.0	-50	-50	31	2.6	-100	40.0	0.10
321103	23	-1.0	29	612	-20	59.0	-20	-50	-100	2.6	-200	37.0	-0.10
321104	37	-0.3	34	624	-20	68.0	-50	-20	-20	2.0	-100	36.0	0.08
321201	25	0.6	-10	330	-20	52.0	-50	-20	-20	2.0	-100	40.0	-0.05
321202	22	0.7	30	512	-20	86.0	-50	-50	-20	1.9	-100	33.0	0.14
321203	25	-1.0	-10	555	-20	51.0	-20	-50	-100	0.6	-200	38.0	0.13
321204	22	-0.3	-10	535	-20	36.0	-20	-20	-20	1.5	-100	35.0	0.16
320601		-0.3	10	639	-20	103.0	-50	-20	-20	3.3	-100	48.0	0.37
320602	55	0.7	-10	688	-20	65.0	-50	-50	-20	3.2	-100	31.0	0.67
320603	38	-1.0	-10	547	-20	75.0	-20	-50	-100	1.2	-200	36.0	0.23
320604				728	-20	77.0	-50	-20	-20	1.1	-100	43.0	0.50
320501	31	-0.3	26	997	-20	65.0	-50	-20	-20	1.6	-100	38.0	0.63
320702	45	0.5	16	617	-20	49.0	-50	-50	-20	2.1	-200	35.0	0.59
320703	50	-1.0	-10	563	-20	72.0	-20	-50	-100	1.7	-100	37.0	0.46
320704	12	0.9	29	520	-20	85.0	-50	-20	-20	-0.2	-100	36.0	0.09
321001	11	-0.3	31		-20	42.0	-50	-20	-20	2.9	-100	37.0	0.34
321002	20	1.2	38	973	-20	39.0	-50	-50	31	2.5	-200	40.0	0.38
321003	50	-1.0	14	620	-20	74.0	-20	-50	-100	1.9	-100	36.0	0.56
321004	14	0.9	22		-20	65.0	-50	-20	-20	-0.2	-100	44.0	1.53
320501		-0.3	30	622	-20	78.0	-50	-20	-20				

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	SO ₄ MG/L-SO ₄	AL MG/L-AL	AS UC/L-AS	N UC/L-N	CD UC/L-CD	CA MG/L-CA	CO UC/L-CO	CR UC/L-CR	CU UC/L-CU	FE MG/L-FE	FR UC/L-FR	MO MG/L-MO	MN MG/L-MN
320302	44	0.5	28	357	-20	74.0	-50	-50	-20	-0.1	-100	32.0	1.23
320303	66	-1.0	24	371	-20	75.0	-20	-50	-100	0.6	-200	40.0	1.22
320304	50	-0.3	29	563	-20	85.0	-50	-20	-20	0.8	-100	38.0	1.13
320401	27	0.3	17	866	-20	57.0	-50	-20	-20	0.3	-100	32.0	0.23
320402	44	0.6	16	366	-20	21.0	-50	-50	-20	-0.1	-100	33.0	0.78
320403	54	1.0	19	503	-20	72.0	-20	-50	-100	-0.5	-200	32.0	0.86
320404	52	-0.3	27	553	-20	84.0	-50	-20	-20	-0.2	-100	36.0	0.94
320501	25	-0.3	43	430	-20	73.0	-50	-20	-20	-0.2	-100	39.0	1.01
320502	37	0.8	53	549	-20	49.0	-50	-50	-20	-0.1	-100	32.0	1.31
320503	72	-1.0	32	576	-20	83.0	-20	-50	-100	0.5	-200	40.0	1.39
320504	58	-0.3	39	554	-20	79.0	-50	-20	85	2.4	-100	38.0	1.11
321301	31	-0.3	15	447	-20	67.0	-50	-20	-20	0.2	-100	41.0	2.37
321302	34	2.0	36	470	-20	78.0	-50	-50	27	3.4	-100	31.0	1.84
321303	24	-1.0	-10	180	-20	67.0	-20	-50	-100	2.6	-200	34.0	2.52
321304	23	-0.3	-10	196	-20	75.0	-50	-20	-20	3.1	-100	33.0	2.19
321401	32	-0.3	-10	546	-20	58.0	-50	-50	25	0.2	-100	37.0	-0.09
321402	32	3.4	-10	365	-20	69.0	-50	-50	397	3.4	-100	27.0	0.27
321403	27	-1.0	-10	434	-20	52.0	-20	-50	-100	0.9	-200	30.0	0.23
321404	36	1.6	-10	370	-20	73.0	-50	-20	-20	2.9	-100	33.0	0.14
321501	14	1.3	-10	644	-20	73.0	-50	-20	-20	1.9	-100	46.0	-0.09
321502	11	1.5	-10	446	-20	79.0	-50	-20	29	0.7	-200	39.0	0.27
321503	9	-1.0	-10	447	-20	61.0	-20	-50	-20	-0.5	-200	32.0	0.23
321504	14	-0.3	-10	453	-20	73.0	-50	-50	-100	0.7	-100	31.0	0.22
321601	44	1.5	-10	974	-20	40.0	-50	-20	-20	1.5	-100	42.0	0.57
321602	44	1.3	15	579	-20	86.0	-50	-20	176	3.3	-100	48.0	0.87
321603	45	0.3	32	570	-20	65.0	-50	-50	92	0.1	-100	32.0	0.80
321604	52	-1.0	13	506	-20	81.0	-20	-50	-20	-0.2	-200	38.0	0.86
321701	55	-0.3	17	630	-20	78.0	-50	-50	-100	0.5	-100	40.0	0.98
321702	41	-0.3	-10	717	-20	62.0	-50	-20	-20	-0.2	-100	37.0	0.16
321703	46	0.7	-10	570	-20	49.0	-50	-50	-20	0.4	-100	31.0	0.32
321704	47	-1.0	14	475	-20	77.0	-50	-100	-100	-0.5	-200	36.0	-0.10
321901	41	-0.3	-10	440	-20	80.0	-50	-20	-20	0.9	-100	37.0	0.14

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	HG UG/L-HG	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NG/L	LINDANE NG/L	METHOXY- CHLOR NG/L	TOXA- PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
312101	-2.0	-50.	3.3	2.8	501.	-10.	-0.03	15.70	-0.01	-0.1	114.00	154.0
312102	-1.0	-50.	2.8	6.5	-20.	-10.	-0.03	-0.20	-0.01	-0.1	-5.00	127.0
312104		-100.	1.5	3.4	390.	-10.	-0.03	1.00	-0.01	-0.1	1.00	10.9
316002	-1.0	-50.	1.7	4.2	20.	-10.	-0.03	-0.20	-0.01	-0.1	11.00	38.2
316003	-0.5	-50.	-1.0	4.8	-50.		-0.03	0.50	-0.01	-0.1	17.00	22.4
310602	-1.0	-50.	2.8	25.0	-20.	-10.	-0.03	3.60	-0.01	-0.1	-5.00	141.0
310603	-0.5	-50.	1.5	13.3	159.		-0.03	20.70	-0.01	-0.1	56.00	22.5
310604		-100.	0.9	4.7	2700.	-10.	-0.03	3.40	-0.01	-0.1	9.00	5.2
324401	-2.0	-50.	4.8		-20.	-10.	-0.03	124.00	-0.01	-0.1	66.00	20.8
324402	-1.0	-50.	4.7	9.4	-20.	-10.	-0.03	1.00	-0.01	-0.1	13.00	79.7
324403	-0.5	-50.	1.8	12.0	-50.		-0.03	8.00	-0.01	-0.1	2.00	38.2
324404		-100.	5.3	29.0	-20.	-10.	-0.03	9.30	-0.01	-0.1	34.00	28.9
324501	-2.0	-50.	15.0	105.0	-20.	-10.	-0.03	159.00	-0.01	-0.1	54.00	14.0
324502	-1.0	-50.	14.9	132.0	-20.	-10.	-0.03	7.20	-0.01	-0.1	21.00	46.2
324503	0.6	-50.	9.1	164.0	-50.		-0.03	0.00	-0.01	-0.1		24.2
324504		-100.	16.4	170.0	-20.	-10.	-0.03	7.30	-0.01	-0.1	11.00	21.8
324505		-100.	16.4	181.0	-20.	-10.	-0.03	3.00	-0.01	-0.1		27.2
324601	-2.0	-50.	16.0	102.0	-20.	26.	-0.03	108.00	-0.01	-0.1	147.00	16.5
324602	-1.0	-50.	14.7	131.0	242.	-10.	-0.03	22.60	-0.01	-0.1	-5.00	25.0
324603	-0.5	-50.	9.1	144.0	-50.		-0.03	18.50	-0.01	-0.1	22.00	11.9
324604		-100.	15.2	212.0	35.	-10.	-0.03	14.70	-0.01	-0.1	43.00	11.5
320101	-2.0	-50.	14.7	119.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	116.00	77.0
320102	-1.0	-50.	13.0	140.0	165.	-10.	-0.03	10.90	-0.01	-0.1	-5.00	6.7
320103	-0.5	-50.	13.2	149.0	-50.		-0.03	1.10	-0.01	-0.1	118.00	53.2
320104		-100.	16.4	170.0	2260.	-10.	-0.03	8.60	-0.01	-0.1	23.00	19.2

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	Hg UG/L-Hg	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NI/L	LINDANE NG/L	METHOXY- CHLOR NG/L	TOXA- PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
320201	-2.0	-50.	16.4	121.0	39.	-10.	-0.03	7.40	-0.01	-0.1	225.00	65.0
320202	-1.0	-50.	14.7	136.0	64.	-10.	-0.03	28.20	-0.01	-0.1	-5.00	46.9
320203	-0.5	-50.	8.9	155.0	-50.	-10.	-0.03	164.00	-0.01	-0.1	44.00	29.0
320204	-2.0	-100.	17.3	168.0	1320.	-10.	-0.03	454.40	-0.01	-0.1	5.00	24.4
321101	-2.0	-50.	16.4	108.0	266.	-10.	-0.03	74.80	-0.01	-0.1	536.00	44.4
321102	-1.0	-50.	14.1	138.0	39.	-10.	-0.03	1.50	-0.01	-0.1	-5.00	89.0
321103	-0.5	-50.	9.3	160.0	-50.	-10.	-0.03	16.90	-0.01	-0.1	8.00	12.8
321104	-2.0	-100.	13.8	177.0	2200.	-10.	-0.03	37.00	-0.01	-0.1	51.00	19.7
321201	-1.0	-50.	14.6	84.0	-20.	-10.	-0.03	12.00	-0.01	-0.1	-5.00	84.7
321202	-0.5	-50.	13.6	87.0	111.	-10.	-0.03	3.00	-0.01	-0.1	44.00	25.5
321203	-0.5	-100.	9.9	116.0	-50.	-10.	-0.03	69.90	-0.01	-0.1	20.00	7.7
321204	-2.0	-50.	13.8	133.0	112.	-10.	-0.03	235.20	-0.01	-0.1	153.00	82.9
320801	-1.0	-50.	8.8	90.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	-5.00	76.2
320802	-0.5	-50.	12.5	96.0	-20.	-10.	-0.03	9.30	-0.01	-0.1	12.00	58.6
320803	-2.0	-50.	9.3	150.0	-50.	-10.	-0.03	-0.03	-0.01	-0.1	-0.01	19.8
320804	-2.0	-50.	15.5	108.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	366.00	82.7
320901	-1.0	-50.	12.5	136.0	-20.	-10.	-0.03	8.00	-0.01	-0.1	-5.00	20.9
320902	-0.5	-50.	10.0	143.0	-50.	-10.	-0.03	-0.03	-0.01	-0.1	49.00	16.7
320903	-2.0	-100.	17.3	184.0	-20.	-10.	-0.03	1360.00	-0.01	-0.1	-1.00	42.9
321001	-1.0	-50.	14.6	106.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	77.40	40.3
321002	-0.5	-50.	14.1	145.0	-20.	-10.	-0.03	2.60	-0.01	-0.1	-5.00	20.7
321003	-2.0	-100.	8.6	154.0	-50.	-10.	-0.03	215.00	-0.01	-0.1	60.00	4.3
321004	-1.0	-50.	18.9	176.0	-20.	-10.	-0.03	1219.00	-0.01	-0.1	-0.01	87.0
320301	-2.0	-50.	7.3	75.0	-20.	-10.	-0.03	2.90	-0.01	-0.1	-35.00	87.0

(Continued)

TABLE B-1. Continued

SAMPLE NUMBER	HQ UG/L-HQ	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN MG/L	LINDANE MG/L	METHOXY- CHLOR MG/L	TOXA- PINE MG/L	2,4-D MG/L	2,4,5-TP SILVER MG/L
320302	-1.0	-50	3.6	67.0	-20.	-10.	-0.03	-0.20	-0.01	-0.1	-3.00	69.2
320303	-0.5	-50	8.2	155.0	-50.	-10.	-0.03	0.60	-0.01	-0.1	44.00	13.4
320304		-100	16.7	170.0	-20.	-10.	-0.03	3.70	-0.01	-0.1		
320401	-2.0	-50	8.2	39.0	-20.	-10.	-0.03	1.30	-0.01	-0.1	100.00	100.0
320402	-1.0	-50	5.0	68.0	-20.	-10.	-0.03	8.40	-0.01	-0.1	-3.00	55.0
320403	0.6	-50	8.2	160.0	-50.	-10.	-0.03	-0.40	-0.01	-0.1	56.00	13.6
320404		-100	14.5	166.0	1800.	-10.	-0.03	13.90	-0.01	-0.1	-1.00	12.1
320501	-2.0	-50	12.0	106.0	-20.	-10.	-0.03	3.00	-0.01	-0.1	115.00	63.6
320502	-1.0	-50	12.5	118.0	-20.	-10.	-0.03	-0.20	-0.01	-0.1	-3.00	100.0
320503	-0.5	-50	8.6	153.0	-50.	-10.	-0.03	1.60	-0.01	-0.1	41.00	19.2
320504		-100	17.3	175.0	152.	-10.	-0.03	3.60	0.01	-0.1	6.00	8.3
321301	-2.0	-50	9.8	82.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	20.10	24.6
321302	-1.0	-50	10.3	74.0	-20.	-10.	-0.03	-0.20	-0.01	-0.1	-3.00	93.7
321303	-0.5	-50	5.9	57.0	-50.	-10.	-0.03	19.90	-0.01	-0.1	92.00	27.0
321304		-100	9.6	81.0	313.	-10.	-0.03	297.60	-0.01	-0.1	6.00	8.5
321401	-2.0	-50	15.7	71.0	-20.	-10.	-0.03	18.00	-0.01	-0.1	48.00	24.7
321402	-1.0	-50	13.0	74.0	-20.	-10.	-0.03	0.40	-0.01	-0.1	-3.00	67.0
321403	-0.5	-50	9.8	80.0	294.	-10.	-0.03	-0.40	-0.01	-0.1	90.00	28.2
321404		-100	16.4	97.0	-20.	-10.	-0.03	196.30	-0.01	-0.1	2.00	17.5
321501	-2.0	-50	11.8	93.0	30.	-10.	-0.03	4.40	-0.01	-0.1	-35.00	19.8
321502	-1.0	-50	10.3	109.0	181.	-10.	-0.03	0.60	-0.01	-0.1	-3.00	134.0
321503	-0.5	-50	7.9	136.0	166.	-10.	-0.03	73.40	-0.01	-0.1	37.00	12.6
321504		-100	12.4	146.0	1090.	-10.	-0.03	693.60	-0.01	-0.1	-1.00	10.3
321601	-2.0	-50	12.5	101.0	175.	-10.	-0.03	11.00	-0.01	-0.1	92.00	12.0
321801	-2.0	-50	12.3	92.0	103.	-10.	-0.03	-1.00	-0.01	-0.1	-35.00	-3.5
321802	-1.0	-50	11.4	123.0	-20.	-10.	-0.03	0.50	-0.01	-0.1	-3.00	
321803	-0.5	-50	8.5	154.0	-50.	-10.	-0.03	-0.40	-0.01	-0.1	17.00	8.9
321804		-100	13.0	159.0	46.	-10.	-0.03	10.60	-0.01	-0.1	23.00	18.2
321901	-2.0	-50	10.3	83.0	-20.	-10.	-0.03	-1.00	-0.01	-0.1	90.00	12.5
321902	-1.0	-50	10.3	109.0	-20.	-10.	-0.03	0.40	-0.01	-0.1	-3.00	43.7
321903	-0.5	-50	8.0	126.0	-50.	-10.	-0.03	2.70	-0.01	-0.1	39.00	19.2
321904		-100	11.4	132.0	-20.	-10.	-0.03	6.50	-0.01	-0.1	-1.00	6.3

TABLE B-2. SOIL DATA

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	PH	INORGANIC NITROGEN UG/GH-N	TOTAL ORGANIC NITROGEN UG/GH-N	TOTAL PHOSPHORUS UG/GH-P	AVAILABLE PHOSPHORUS UG/GH-P	TOTAL SULFUR UG/GH-S
324051	10/ 1/76	0.3	8.6	32.8	16	160	7	85
324061	10/ 7/76	18.7	8.7	39.7	18	206	1	85
324062	10/ 7/76	21.7	9.0	41.2	29	201	1	65
324092	10/ 3/76	5.5	8.8	61.9	27	231	14	359
324092	10/ 3/76	6.1	8.6	22.1	100	192	9	556
324093	10/ 3/76	8.5	8.8	14.8	28	168	6	264
324094	10/ 3/76	9.8	9.0	21.6	20	223	5	367
324095	10/ 4/76	11.6	9.0	22.6	17	258	13	129
324101	10/ 6/76	2.7	8.3	33.0	227	337	20	385
324102	10/ 6/76	16.2	8.5	34.1	28	188	9	74
324121	0/ 0/ 0	16.9	8.5	86.4	29	400	13	107
324122	0/ 0/ 0	24.2	9.2	24.6	26	259	7	118
324123	10/ 3/76	28.1	8.5	23.5	6	162	3	136
324161	10/ 6/76	12.8	8.5	33.4	7	167	7	64
324191	10/ 6/76	14.1	9.0	8.0	321	79	7	80

(Continued)

TABLE B-2. Continued

SAMPLE NUMBER	CATION EX-CAP MEG/100G	EXTR AL UG/GH	EXTR B UG/GH	EXTR CD UG/GH	EXCH. CA UG/GH	EXTR. CO UG/GH	EXTR. CR UG/GH	EXTR. CU UG/GH	EXTR. FE UG/GH	EXTR. PB UG/GH	EXCH. MG MG/GH	EXTR. HG UG/GH
324051	0.77	-5	0.23	-0.02	1.92	-0.12	-0.03	0.3	9	-1.2	0.03	25
324061	0.89	-5	0.43	0.02	2.17	-0.12	-0.05	0.2	11	-1.2	0.03	10
324062	0.26	-5	0.44	-0.02	1.38	-0.12	-0.05	0.2	14	-1.2	0.02	6
324091	0.50	-5	0.35	-0.02	1.45	-0.12	-0.05	0.6	18	-1.2	0.02	7
324092	0.85	-5	0.48	0.04	1.76	-0.12	-0.05	0.8	15	-1.2	0.02	8
324093	0.61	-5	0.58	0.03	2.72	-0.12	-0.05	2.0	44	-1.2	0.03	14
324094	0.38	-5	0.42	0.02	1.30	-0.12	-0.05	1.1	28	-1.2	0.01	11
324095	0.29	-5	0.30	0.03	1.02	-0.12	-0.05	1.1	23	-1.2	0.02	10
324101	0.86	-5	0.29	0.06	1.72	-0.12	-0.05	1.9	40	-1.2	0.02	41
324102	0.24	-5	0.24	0.03	1.72	-0.12	-0.05	1.0	31	-1.2	0.02	16
324121	1.14	-5	0.41	0.05	2.63	-0.12	-0.05	1.3	52	-1.2	0.03	20
324122	0.84	-5	0.54	-0.02	2.52	-0.12	-0.05	0.6	20	-1.2	0.04	18
324123	0.39	-5	0.31	-0.02	1.33	-0.12	-0.05	0.7	34	-1.2	0.03	13
324161	0.25	-5	0.39	-0.02	1.26	-0.12	-0.05	0.2	15	-1.2	0.02	7
324191	0.33	-5	0.35	0.04	1.74	-0.12	-0.05	1.8	9	-1.2	0.03	8

(Continued)

TABLE B-2. Continued

SAMPLE NUMBER	EXTR. NI UG/GM	EXCH. K MG/GM	EXCH. NA MG/GM	EXTR. ZN UG/GM	ENDRIN NG/GM	LINDANE NG/GM	METHOXYCHLOR NG/GM	TOXAPHENE NG/GM	2,4-D NG/GM	SILVER NG/GM	TOTAL D UG/GM	TOTAL D UG/GM	TOTAL D UG/GM
324091	-0.25	0.018	0.01	0.37							5.2	-2	28.
324061	-0.25	0.017	-0.01	0.29							3.5	-2	21.
324062	-0.25	0.008	-0.01	0.61							3.7	-2	34.
324091	-0.25	0.009	0.01	1.97	-0.6	250	-0.01	-0.6	-0.13	0.87	5.4	-2	21.
324092	0.66	0.011	0.01	2.45	-0.6	1116	-0.01	-0.6	-0.13	1.21	4.6	-2	23.
324093	0.67	0.022	-0.01	12.00							4.4	-2	43.
324094	0.55	0.011	-0.01	4.18							4.6	-2	28.
324095	0.55	0.006	-0.01	3.31							3.1	-2	34.
324101	0.78	0.020	0.01	4.26	-0.6	480	-0.01	-0.6	-0.13	2.43	5.4	-2	20.
324102	-0.25	0.018	0.01	1.79	-0.6	485.	-0.01	-0.6	-0.13	2.26	2.1	-2	19.
324121	-0.25	0.043	0.07	3.27							3.0	-2	51.
324122	0.44	0.030	0.07	0.78							1.9	-2	36.
324123	0.78	0.016	0.02	1.02							2.6	-2	19.
324161	-0.25	0.009	0.02	0.39							3.6	-2	19.
324191	-0.25	0.023	0.01	0.47							4.6	-2	39.

(Continued)

TABLE B-2. Continued

SAMPLE NUMBER	TOTAL Cd UG/GM	TOTAL CR UG/GM	TOTAL CU UG/GM	TOTAL FE MG/GM	TOTAL PB UG/GM	TOTAL MG MG/GM	TOTAL MN UG/GM	TOTAL HG UG/GM	TOTAL NI UG/GM	TOTAL K MG/GM	TOTAL NA UG/GM	TOTAL ZN UG/GM	TOTAL AS UG/GM	TOTAL SE UG/GM
324051	3	12	7	3.1	-10	6.8	180	-1	15	5	2.1	15	4	-1
324061	-2	11	6	2.9	-10	4.8	115	-1	12	6	1.4	14	2	-1
324062	-2	12	5	3.2	-10	7.3	116	-1	12	4	1.4	15	3	-1
324091	-2	9	3	2.9	-10	2.6	80	-1	12	7	1.6	14	1	-1
324092	2	8	6	2.9	-10	3.5	86	-1	11	5	2.0	16	1	-1
324093	2	12	8	3.1	-10	11.0	107	-1	15	5	2.6	46	1	-1
324094	2	9	3	2.9	-10	5.6	91	-1	11	4	2.5	19	2	-1
324095	2	9	7	2.9	-10	5.9	100	-1	15	4	1.8	18	1	-1
324101	2	11	9	3.1	-10	2.7	109	-1	12	5	2.5	22	2	-1
324102	2	8	4	2.8	-10	3.4	180	-1	9	4	1.3	8	1	-1
324121	3	9	7	3.0	-10	9.0	141	-1	16	5	1.0	32	2	-1
324122	2	8	5	2.7	-10	7.1	98	-1	11	5	0.7	8	2	-1
324123	-2	9	5	2.9	-10	4.0	91	-1	10	4	2.6	17	1	-1
324161	2	16	5	3.2	-10	3.1	119	-1	9	3	2.2	12	-1	-1
324191	2	16	11	3.0	-10	9.1	126	-1	12	5	1.8	13	-1	-1

APPENDIX C

EXISTING WELL LOCATIONS AND WATER TABLE ELEVATION

EXISTING WELLS - LOCATION & WATER TABLE ELEVATION

No. 1

Location - 112 West Madison - 113' N. of E. Madison Avenue

Owner - Howard Drake

871.64 B.M. Elev. = TOC

53.59 B.M. to SWL

818.05 SWL Elev.

No. 2

Location - 175' East of E. John Paul Road

Owner - Joe Shelden

873.25 Elev. TOC

873.27 B.M. Elev.

49.28 TOC to SWL

.02' BM to TOC

823.97 SWL Elev.

No. 3

Location - 400' East of Well No. 2, 575 E. East John Paul Road

Owner - Judy Tracy

898.71 Elev. TOC

898.73 B.M. Elev.

72.56 TOC to SWL

.02' B.M. to TOC

826.15 SWL Elev.

No. 4

Location - 402 East Madison - 115' North of E. Madison Avenue

Owner - Ken Babcock

875.92 B.M. Elev. = TOC B.M. = Conc. Base

44.23 B.M. to SWL

831.69 SWL Elev.

No. 5

Location - 119 Hilltop Drive - between railroad tracks W. of Street

Owner - Robert Jewett

869.30 B.M. Elev. = SE cor. of conc.

5.25 B.M. to TOC

864.05 Elev. TOC

44.95 TOC to SWL

819.10 Elev. SWL

(Continued)

No. 6

Location - 106 Rogers - cor. Rogers and Greenman St.

Owner - Robert Boynton

877.17 Elev. B.M. = TOC

48.22 TOC to SWL

828.95 SWL Elev.

No. 7

Location - 1155 East High Street (Frank's Beverage)

Owner - Mrs. Bva

879.31 Elev. TOC

37.10 TOC to SWL

842.21 Elev. SWL

879.32 B.M. Elev.

0.02 B.M. to TOC

No. 8

Location - Route 26 and St. Mary's (Standard Station)

880.97 Elev. TOC

45.31 TOC to SWL

835.66 SWL Elev.

880.99 B.M. Elev.

0/02' B.M. to TOC

No. 3221

Location - North on Route 26 on west side of road

Owner - Sawyer

876.37 Elev. TOC

38.64 TOC to SWL

837.73 Elev. SWL

882.36 B.M. Elev.

5.99 B.M. to TOC

No. 9

Location - North on Route 26, across from cemetery on east side of road

872.81 B.M. Elev = TOC

35.34 TOC to SWL

837.47 SWL Elev.

GLOSSARY

Adsorption: A process in which soluble substances are attracted to and held at the surface of soil particles.

Advanced wastewater treatment: Additional treatment designed to reduce concentrations of selected constituents present in wastewater after secondary treatment.

Alkali soil: A soil with a high degree of alkalinity (pH of 8.5 or higher) or with a high exchangeable sodium content (15 percent or more of the exchange capacity) or both.

Aquiclude: A geologic formation which is porous and capable of absorbing water but will not transmit it rapidly enough to supply a well or spring.

Aquifer: A geologic formation or strata that contains water and transmits it from one point to another in quantities sufficient to permit economic development.

Consumptive use: Synonymous with evapotranspiration.

Conventional wastewater treatment: Reduction of pollutant concentrations in wastewater by physical, chemical, or biological means.

Drainability: Ability of the soil system to accept and transmit water by infiltration and percolation.

Effective precipitation: Precipitation that enters the soil and is useful for plant growth.

Evapotranspiration: The unit amount of water lost from a given area by transpiration, building of plant tissue, and evaporation from the soil surface, snow, or intercepted precipitation in a specified period of time.

Fixation: A combination of physical and chemical mechanisms in the soil that act to retain wastewater constituents within the soil, including adsorption, chemical precipitation, and ion exchange.

Groundwater: The body of water that is retained in the saturated zone that tends to move by hydraulic gradient to lower levels.

Groundwater table: The free surface elevation of the groundwater; this level will rise and fall with additions or withdrawals.

- Infiltration:** The entrance of applied water into the soil through the soil-water interface.
- Infiltration-percolation:** An approach to land application in which large volumes of wastewater are applied to the land, infiltrate the surface, and percolate through the soil pores.
- Irrigation:** Application of water to the land to meet the growth needs of plants.
- Land application:** The discharge of wastewater onto the soil for treatment or reuse.
- Loading rates:** The average amount of liquid or solids applied to the land over a fixed time period, taking into account periodic resting.
- Lysimeter:** A device for measuring percolation and leaching losses from a column of soil; also a device for collecting soil water in the field.
- Micronutrient:** A chemical element necessary for plant growth in amounts below 1 mg/L.
- Mineralization:** The conversion of an element from an organic form to an inorganic form as a result of microbial decomposition.
- Overland flow:** Wastewater treatment by spray-runoff (also known as "grass filtration") in which wastewater is sprayed onto gently sloping, relatively impermeable soil that has been planted to vegetation. Biological oxidation occurs as the wastewater flows over the ground and contacts the biota in the vegetative litter.
- Pathogenic organisms:** Microorganisms that can transmit diseases.
- Percolation:** The movement of water through the soil pores once it has passed the soil-water interface.
- Phytotoxic:** Toxic to plants.
- Primary effluent:** Wastewater that has been treated by screening and sedimentation.
- Refractory organics:** Organic materials not removed in secondary treatment.
- Ridge-and-furrow method:** The surface application of water to the land through formed furrows; wastewater flows down the furrows, and plants may be grown on the ridge.
- Saline soil:** A nonalkali soil containing sufficient soluble salts to impair its productivity.
- Secondary treatment:** Treatment of wastewater by physical, chemical, or biological means such as trickling filters, activated sludge, or chemical

precipitation and filtration.

Sewage farming: Originally involved the transporting of sewage to rural areas for land disposal. Later practice includes reusing the water for irrigation and fertilization of crops.

Soil texture: The relative proportions of the various soil separates--sand, silt, and clay.

Soil water: That water present in the soil pores in an unsaturated zone above the groundwater table.

Spraying: Application of water to the land by means of stationary or moving sprinklers.

Spray-runoff: See overland flow.

Tilth: The physical condition of a soil as related to its ease of cultivation.

Transpiration: The net quantity of water absorbed through plant roots and transpired plus that used directly in building plant tissue.

Viruses: Submicroscopic biological structures containing all the genetic information necessary for their own reproduction but dependent for reproduction upon living cells.